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DAONELLA IN JAPAN

THE HALOBIIDAE FROM THAILAND —(211)

By

T. KOBAYASHI and A. TOKUYAMA

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DAONELLA IN JAPAN*

By

Teiichi KOBAYASHI and Akira TOKUYAMA

With I—IV Plates

I. Introductory Note

This is a companion paper with "*Halobiae* in Nippon" by AOTI and the senior author in 1943 and consists of the following 4 parts:

1. *Daonella* from Zohoin in Sakawa basin
2. *Daonella* in the Japan Province
3. Note on the Distribution of *Daonella*
4. Description of *Daonella* in Japan

The genus is represented in the Triassic of Japan by 15 species in addition to 2 subspecies, including 5 new species and 2 new subspecies, with which 5 in 8 groups of KITTL's classification are represented. They are distributed in the Rifu, Zohoin and Atsu series, but each has its own assemblage of species. Therefore 3 zones can be distinguished as follows:

3. *Daonella yoshimurai* zone in the Ladino-Carnic Atsu series
2. *Daonella subquadrata* zone in the upper Ladinic Zohoin series
1. *Daonella multistriata* zone in the lower Ladinic-upper Anisic Rifu series

Daonella as a genus was most flourished in the Alpine or Tethyan geosyncline in the Ladinic epoch. While 2 species of the Rifu series are closely related to *D. americana* and SMITH's *D. moussoni*, most others of the two other species show affinities with the Alpine and Tethyan species. Most species of *Daonella* so far reported from Ussuri have close relatives in Japan.

A brief note is added to the end of this monograph to supplement to *Halobiae in Nippon*.

II. *Daonella* from Zohoin in Sakawa basin

Zohoin in Sakawa basin, Kochi Pref. (Prov. Tosa) is the most famous locality of *Daonella* in Japan known from the cradle of her geologic research. MOJSISOVICS (1888) was the first to describe *Daonella* of two new species, *kotoi* and *sakawana*, from this locality. Subsequently, studies on *Daonella* of Zohoin were repeated by KITTL, 1912, DIENER, 1915, YABE and SHIMIZU, 1927 and the senior author, 1931. In the study on the Rifu fauna, YABE and SHIMIZU (1927) classified the *Daonella* from Zohoin into 3 species and 2 varieties, where *Daonella kotoi* var. *alta*, *Daonella densisulcata* and its variety *subquadrata* were new. They correlated the *Daonella* bed of Zohoin with the upper *Daonella* bed of Rifu, Prov. Rikuzen (Miyagi Pref.) because *densisulcata* was common between them. SHIMIZU (1930) reported the occurrence of *Protrachyceras* aff. *archelaus* (LAUBE) and *This-*

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bites orientalis SHIMIZU in the series, where the former species is well known as an upper Ladinic zone index. This agrees with the chronology that the senior author (1931) reached by his preliminary study. At that time he distinguished the Zohoin collection into 4 species and 4 varieties including *Daonella indica* and 3 new varieties. In 1927 YEHARA proposed Zohoin series for the Middle Triassic formation of the Sakawa basin. Later however, it was found that his Zohoin series includes much of the Permian. Therefore the senior author (1931) restricted the usage of the Zohoin series to the *Daonella* bed.

It is composed mainly of dark gray or black mudstone beside some sandstone intercalations. Its type locality is a small narrow low hill adjacently to the east of Sakawa town. Almost all fossils collected at this locality belong to *Daonella*. *Pseudomonotis ochotica* was reported therefrom by MOJSISOVICS erraneously, as noted by DIENER, YABE and SHIMIZU and the senior author, because *ochotica* has never been actually procured from Zohoin, notwithstanding the fact that innumerable collectors have visited there. "*Gervillia*" and a few ammonites may be all other fossils so far known from Zohoin.

The Zohoin collection which was accumulated in this institute by Prof. B. KOTO and many others is a large one comprising various forms and constitutes the main objects of this study. Naturally they must be brought into comparison with *Daonella* from Rifu and other localities. In 1940 Prof. HANZAWA invited the senior author to Sendai to give a lecture on the Geology of Eastern Asia. During this stay he could make a study on YABE and SHIMIZU's types from Rifu and Zohoin. Furthermore he was fortunate to have happy opportunities to study many originals of SMITH, MOJSISOVICS and others at his visit to Washington D.C., Wien and Bonn during the years from 1931 to 1934. On this occasion the author wishes to record his sincere thanks to Dr. R.S. BASSLER of the U.S. National Museum, the late Dr. John B. REESIDE of the U.S. Geological Survey, the late Prof. J. PIA of the Naturhistorishes Museum zu Wien, the late Prof. J. WANNER of the Universität zu Bonn and Prof. S. HANZAWA of the Tohoku University at Sendai.

In 1943 when the senior author has published *Halobiae in Nippon* with AOTI, it was his plan to take up *Daonella in Japan* in the next step. It was soon attempted with HUKASAWA and then with ISHII. Interrupted by other works however, the material was left untouched for more than ten years. Recently he resumed it with assistance of the junior author.

As the result 11 species and 2 subspecies are distinguished and referred to KITTL's groups as follows:

2 nd group of *moussoni*
Daonella tenuistriata KOBAYASHI & TOKUYAMA, new species

3 rd group of *tyrolensis*
Daonella alta YABE & SHIMIZU
Daonella indica BITTNER
Daonella cfr. *spitiensis* BITTNER
Daonella iwayai KOBAYASHI & TOKUYAMA, new species
Daonella kotoi MOISISOVICS
Daonella sakawana MOJSISOVICS

4 th group of *sturi-lommeli* (?)
Daonella subquadrata YABE & SHIMIZU
Daonella subquadrta zohoinensis KOBAYASHI & TOKUYAMA, new subspecies
Daonella subquadrata symmetrica KOBAYASHI & TOKUYAMA, new subspecies

5 th group of *grabensis*
Daonella pectinoides KOBAYASHI & TOKUYAMA, new species

6 th group of *pichleri*
Daonella asymmetrica KOBAYASHI & TOKUYAMA, new species
Daonella hiratai KOBAYASHI & TOKUYAMA

In this collection *subquadrata* (inclusive of 2 subspecies) is most abundant and *indica* and *koto*i are the next. The other species are rare. Systematically, they are included in KITTL's 2nd to 6th groups. *D. tenuistriata* is aberrant and not typical of the second group but more or less related to the third group. *D. alta* is typical of the third group which comprises many relatives in the Tethys fauna. *Indica* is widely distributed in the Tethys-Asiatic region in the upper Ladinic to the lower Carnic. In Portuguese Timor it occurs in the *reitzi*- or *lommeli*-zone of the autochthonous Trias, and in the Trias of the Deckencomplex it coexists with *D.* aff. *kittli* (WANNER, 1956). In the Himalayas, it is stated by DIENER (1912) that "there is no distinct stratigraphical horizon characterized by the presence of *Daonella indica*, as had been suggested by BITTNER." There the *indica*-horizon overlies the *archelaus*-zone and *indica* is sometimes collected from the lower Carnic. In the Alps, it is found most often in the Esino and Marmolata stages and sometimes in the Cassian stage or *aon*-zone (KITTL, 1912). *Spitiensis* is a member of the *indica*-group in the lower part of the zone in Spiti. *Iwayai* is related to *arzelensis* KITTL from the upper Ladinic Wettersteinkalk stage of Innsbruck and cfr. *bulogensis* by KRUMBECK from Timor. Therefore this is also of the Tethys-Asiatic fauna. *Kotoi* and *sakawana* are, though not typical of this group, allied to some inequilateral forms of the group such as *kittli*, *latecosta* and *tripartita*. The "Formenkreis" of *subquadrata* to which *lilintana* is included, is distributed in Indonesia, Timor, and the Himarayas. The *pichleri* group, to which *asymmetrica* and *hiratai* is included, is also distributed widely in the Tethys-Asiatic regions. While *pichleri* is found commonly in the Alps, KRUMBECK described its subspecies from Timor. A very unusual form is *hiratai* but its ally is found in VOLZ's Sumatra-fauna. Finally, *pectinoides* is a relative of *zellensis* which is a common Tethys member.

In short all Zohoin species of *Daonella* but the first are comparable with Tethys and Asiatic species. *Subquadrata*, *indica* and *spitiensis* are all common Asiatic members, while *alta* and *pectinoides* are relatives of Tethys elements and the *pichleri* group has more species in Tethys than Asia. The Alpine relatives suggest upper Ladinic for the Zohoin series. The *tyrolensis* group is distributed in the Esino stage or the lower *archelaus* zone. *Indica* ranges from the Buchenstein stage or the *reitzi* zone to the Cassian stage. *Pichleri* found in the Wengen stage or the upper *archelaus* zone, and the group of *zellensis* occurs in the Cassian stage. Therefore, ignoring the aberrant forms, the Zohoin fauna can be safely correlated with the Ladinic ones in the Alps.

The Zohoin specimens of *Daonella* are all internal and external moulds. Because the test is gone, its thickness is actually immeasurable. It can be presumed, however, that the shell was not thick, because the difference of ribbing between the two moulds is inconcievable.

Two valves of *Daonella hiratai* are wide open but still united. There are a few other examples of such preservation. All others are, however, separate valves. Nevertheless their outlines are generally undamaged. Because the hinge and muscles are poor in *Daonella*, two valves are easily separable from each other. Detached valves are scattered or crowded on slabs, but they are never

so much accumulated as can be called a shell bank. The shells often lie with their convex side above, but the reverse orientation is not rare. It is noted on some slabs that umbones are directed to a certain similar direction. It is remarkable also that some slabs contain only small shells. As a tendency small shells may be said rare or very uncommon where large and medium sized ones are found abundant. The small shells which are not far removed from the *Posidonia*-like stage are not dwarfs, but immature shells. Then, what does the difference in the shell size of the crowd mean? Does it have something to do with the hatching season? It is probable also that mature and immature shells were sorted by wave of current.

At all events the Zohoin fauna is an interesting example of overwhelming majority of a certain genus in a small fauna. Its number of the known genera is reduced to 2, if the ammonites are exotic floats. *Daonella* is rich not only in number of individuals but also in the number of species and subspecies. It is indeed an extraordinary profusion to find 12 species of *Daonella* in addition to 2 subspecies at one locality. It must not be overlooked, however, that the majority of *Daonella* belongs to 3 species, or precisely speaking, more than a half or approximately 3/5 to *subquadrata* and its two subspecies, about a quarter or a fifth to *kotoi* and a fifth or so to *indica* plus cfr. *spitiensis*. In the remaining 7 species 6 are each represented by a single specimen. This sensus shows that more than 95% of the Zohoin fauna are occupied by 3 species of *Daonella*. Their prosperity means that the muddy bottom of Zohoin in the Ladinic sea has been particularly favourable for them.

The occurrences of these species are restricted to Shikoku island or the Sakawa basin, except for *D. indica* which is widely distributed from the Alps to Japan through the Himalayas and South China and *D. spitiensis* known from Spiti. Compared to the large forms of *indica* in the calcareous facies the Japanese examples of the species are smaller. *D. spitiensis* is also a little larger than *D.* cfr. *spitiensis*. Mature shells of the other Zohoin species seem to be near the average size of *Daonella*.

Because these shells are thin but undamaged, their habitat is inferred to have had a tranquil bottom of moderate depth, although it was agitated by current or had waves at least temporarily, seeing that two valves are mostly separated from each other and many shells take stable orientation. In many characteristics the *Daonella* bed of Zohoin resembles the so-called *Posidonienschiefer*.

The shells of *Daonella* are nearly flat except the umbonal region which is a little inflated. It is difficult to say about the original convexity, because it is indeterminable how far the shell was depressed secondarily. However, it is noteworthy that the shells are mostly flattened without yielding any visible cracks. This is probably because thin shells were flattened extremely slowly by compaction of mother rock. There are of course some cracks which were probably products by deformation of mother rock. The secondary deformation of the shell outline varies to some degrees among the specimens. In an immature specimen of *subquadrata* two valves are nearly identical in outline, but it is quite obvious in the holotype of *hiratai* that its two valves are diagonally compressed to some extent. There is, however, no specimen from Zohoin which is so strongly deformed that its specific identification is made impossible.

III. *Daonella* in the Japan Province

In Japan *Daonella* occurs in the Zohoin series in Kochi and Tokushima Pref. (Prov. Tosa and Awa), the Atsu series in Yamaguchi Pref. (Prov. Nagato), the Rifu series in Miyagi Pref. (Prov. Rikuzen) and probably its equivalent in Kyoto Pref. (Prov. Tamba). Recently NAKAZAWA (1958) reported *Daonella* (?) sp. with *Nuculana* sp. and *Monophyllites* cfr. *sphaerophyllus* from the top of the Oro formation in Kyoto Pref. It was however, too fragmentary to make an exact determination.

Previously the senior author (1931) has described *Daonella* cfr. *kotoi* var. *alta* and several other fossils from the Sambosan limestone at Sambosan, Kami-gun, Kochi Pref. and suggested Ladino-Carnic age for this fauna. Because of imperfect preservation, however, the reference to *Daonella* cannot be warranted. Lately the junior author (1957) found that *Rhynchonella sambosanensis* belongs to *Holcorhynchia* whose range is Carnic to Dogger. Therefore he suggested Carnic for the age of the limestone. It seems then probable that the *Daonella* in question is a *Halobia*.

Beside Zohoin *Daonella* occurs in the Zohoin series at Okazaki-goe adjacently west of Sakawa town and Yokoyama-dani to the northeast of Zohoin. The strip of the series extends farther to the east into Ino area from the basin. There HIRATA (1939) discovered three localities, i.e. (1) west of Okuna, (2) between Okuna and Kuroiwa-dani and (3) Kuroiwa-dani to which (4) Koretomo between Ino and a locality at Konai was later added by YAMAMOTO, OKUMURA and NISHIMURA (1941).

The *Daonella*-bearing rocks at these 4 localities of Ino area as well as at Okazaki-goe are similarly fine yellowish slabs altered from the black shale of the Zohoin type, but somewhat finer than the typical Zohoin specimens. It is a remarkable fact that most shells are small and undamaged. The *Posidonia*-like stage is often seen in the umbonal region of about 1 mm or less. The immature shells are commonly 5 to 10 mm long, but a complete specimen attains the length of 2 cm. This collection comprises only a few large but imperfect ones. Fragments of large shells are, however, not rare. These shells and fragments are gregarious on bedding planes. This aspect combined with the fact that there is no example of two valves united suggests the effect of sorting of some strength for the gregarious occurrence of the shells. "*Natica*" sp. and "*Dentalium*" sp. are reported as two associates with *Daonella* in Ino area.

As most shells are either immature or imperfect, their taxonomy cannot be very accurate. Most of them are, however, identifiable with *indica*, *kotoi* and *subquadrata zohoinensis* where *indica* is characterized by high outline, *kotoi* by rounded and diagonally prolonged outline and flattened wide ribs and *subquadrata zohoinensis* by the fairly developed *Posidonia*-like stage, diagonally elongated outline and numerous ribs. Beside them there is a common form which is an unnamed variety of *kotoi* having flat trifurcated ribs in the median part.

Stimulated by the find of *Daonella* and other Mesozoic fossils in Tokushima Pref. by SHINOHARA (1941), the senior author carried out the geological survey with IWAYA (1941) with the result that the highly complicated imbrication of Sakuradani was brought to light. On this occasion *Daonella* was found at Usugatani, Fujinohira, Gorodani and Junisha in the Zohoin series of the Fujinohira Decke. Later HIRATA (1950) found *Daonella* at Semidani in the western extension of the series, while SUYARI (1958) discovered *Daonella* in a mudstone at Kumagatani, Tomioka-town which is most eastern locality of the series in Shikoku island. YAMASHITA and others (1956) proposed "Usugatani formation" for the

Daonella bed in Tokushima Prefecture, but it is a superfluours name because there is no question about its synonymy with the Zohoin series.

In comparison with yellowish slabs of Ino the *Daonella* shale of Sakuradani area is more coarse grained and its colour dark grey or black. The most common member is *indica*, followed by *subquadrata* and *subquadrata symmetrica*. *Kotoi* is common in Sakuradani as well as in Ino area; *pectinoides* is a rare species in Zohoin; but common in Sakuradani. *Trachyceras* (*Protrachyceras*?) 2 spp. are reported from Junisha and Inotani on the opposite side of Fujinohira and *Ptychites* (?) from Gorodani, but none of them is as yet described.

In Sakawa–Ino area the Zohoin series lies on the Permian or the Permo-Triassic on the south side. It forms an arcuate strip delimited by a thrust from the northern zone where the Permian formation and the Upper Triassic Kochigatani series exist. Likewise in Sakuradani area the Fujinohira Decke which bears the Zohoin series is thrust from the north by the low angled Hisone Decke where the Kochigatani is found. The northerly lapping of the Kochigatani over the Zohoin series is noteworthy because it reveals the regression which has taken place in the peri-orogenic zone of the Akiyoshi mountains in the late Ladinic epoch.

In the inner zone of West Japan the senior author (1935) has described *Daonella yoshimurai* from the Atsu series at Shirogahara, Mine city, Yamaguchi Pref. It has several wide, weak, flat-topped ribs only in the median part and undoubtedly belongs to KITTL's *moussoni* group. Recently the junior author added 2 species of *Halobia* and one of *Oxytoma*, all new (1959). The *Daonella* horizon lying conformably below the lower Carnic Hirabara formation is in the upper part of the Atsu series. Therefore its age is generally accepted to be latest Ladinic, if not earliest Carnic.

In North Japan the occurrence of *Daonella* was first reported by YABE from Rifu, north of Sendai, Miyagi Pref. Later YABE and Shimizu (1927) divided the Rifu series into the upper and lower *Daonella* beds and subdivided the lower one into the upper or *Monophyllites* zone and the lower or *Ptychites* zone. The Rifu fauna is a rich one comprising 25 forms in *Spiriferina*, *Myoconcha*, *Pleuronautilus*, *Gymnotoceras*, *Hollandites*, *Beyrichites* and other Molluscan genera which are related partly to the Middle Triassic of Himaraya and partly to the fauna of the Star Peak formation of the *Daonella dubia* zone of Nevada. *Daonella kotoi* var. *multistriata* and *Daonella densisulcata* were described from the upper *Daonella* bed and the *Monophyllites* zone, but no *Daonella* is contained in the *Ptychites* zone. YABE and SHIMIZU considered the fauna to be Ladinic in age and correlated the upper *Daonella* bed to the Zohoin series, because *D. densisulcata* occurs also at Zohoin. Their *D. densisulcata* of Zohoin, however, is *D. subquadrata* subsp. *zohoinensis*. Because there is no species of *Daonella* common between the Zohoin and Rifu series and because the Rifu fauna reveals affinities with the Anisic ones, the Rifu fauna is a little older than the Zohoin and probably Ladino-Anisic. According to NAKAZAWA and ICHIKAWA (1951) the structure exposed at the cutting of Rifu is a monocline, instead of an anticline as understood by YABE and SHIMIZU. Accordingly the above zonation becomes doubtful. Recently BANDO (1958) found *Protrachyceras* cfr. *reitzi* in addition to *Ptychites*, *Tropogastrites*, *Gymnites*, *Megalodus* and others and located the Rifu series at lower Ladinic. The two Rifu species of *Daonella* are closely related to *D. americana* and SMITH's *moussoni* and specifically distinct from any of the Zohoin and Atsu series. This conclusion matches with the general aspect of ammonites which appears most

related to that of the *dubia* zone which is in turn considered Anisic by MULLER (1939), although *P.* cfr. *reitzi* is contained as ons of a few allies to the Alpine or Tethys fauna. Therefore it is more reasonable to extend the range of Rifu from lower Ladinic to upper Anisic than to restrict to lower Ladinic. The Rifu series is exposed at a few places beneath Neogene blanket. Its stratigraphic relation to the Anisic *Hollandites* beds of the Inai series in the southern Kitakami mountains is indeterminable.

As discussed already, the Zohoin fauna is a correlative of the upper Ladinic *archelaus* zone or *lommeli* zone. *Daonellae* of the Zohoin series comprise several close relatives of the Tethyan species beside *indica* which was wide spread from the Alps to Japan through the Himaraya, South China and Indonesia. The stratigraphic relation of this series to the Kochigatani is also yet unsolved, because they are distributed in different tectonic belts.

In Yamaguchi Pref. the Mine series overlies the Atsu and overlapping the latter, the former extends toward the north. The two series yield no ammonites, but the age of the Mine series can be determined by *Halobia* and other pelecypods (KOBAYASHI & AOTI, 1943, TOKUYAMA, 1959).

As discussed above, three *Daonella* zones are distinguished in Japan, where the middle one reveals the acmic prominence. The *yoshimurai* zone where *Daonella* and *Halobia* are coexistent is transition from the *Daonella* to the *Halobia* epoch in Japan.

ICHIKAWA proposed Matsushiman for the Rifu fauna, while he combined the Zohoin and Atsu faunas in his Fujinohiran, notwithstanding the fact that no species is common between the Zohoin and Atsu faunas. By this reason the senior author emphasized that they are two distinct units. In agreement with this opinion, NAKAZAWA segregated the latter part out of the Fujinohiran for which he proposed Arakuran, in taking the Arakura formation in Kyoto Pref. for the type and referring the Atsu series to it. There is, however, no fossil common between the Atsu and Arakura formations. The three *Daonella* zones and their ages are as follows:

Daonella yoshimurai zone——Ladino-Carnic Atsu series
Daonella subquadrata zone——Upper Ladinic Zohoin series
Daonella multistriata zone——Lower Ladinic to Upper Anisic Rifu series.

The two species of *Daonella* of the lower zone are related to the North American ones whereas the Tethyan affinity is distinct in the *Daonella* of the middle zone. *D. yoshimurai* is also allied to the Alpine *D. paucicostata.*

Finally, Ussuriland belongs to the same province with Japan, insofar as *Daonella* is concerned. According to KRYSTOFOVICH (1926), it occurs in the Middle Triassic shale at Lianchiho. According to WITTENBURG (1927) the black monotonous shale, 150 m thick, at Lan-tschi-che lies on the tuffaceous marine Permian and is overlain by the Jurassic quartzose sandstone. It yields *Daonella kotoi*, *Daonella sakawana* and *Lingula* sp. Hence the *Daonella* shale is equivalent to the Zohoin series. It is certainly remarkable that this series is isolated from either the older or the younger Triassic formation in Ussuri as in Japan. According to KIPARISOVA (1954) the Ladinic bed of the Maritime Province yields *Daonella densisulcata*, *D.* "*moussoni*" and *Posidonia wengensis* beside *Trachyceras* aff. *furcatum*, *Gymnotoceras* sp. and *Xenodiscus* (*Xenaspis*) aff. *middlemissi*. Her *moussoni* (pl. 18, figs. 5, 6) appears to agree with the *tyrolensis*-group better than the *moussoni*-group, because ribs are regular and distinct through the valve. It may be related to *indica* and allies. The Ladinic, 400 to 800 m thick in the Far East, is

composed mainly of well stratified siltstone to which light coloured quartzose sandstone is added (BELIAEVSKY et al., 1958). The siltstone contains *Daonella densisulcata* and *D. moussoni* abundantly, beside *Protrachyceras*, *Gymnotoceras* and *Ptychites* in rare instances. It can hardly be overlooked that the Ladinic fauna of Ussuri is intimately related to the Rifu and Zohoin faunas in Japan.

In conclusion the authors express their cordial gratitudes to Messrs Kagetoshi HASHIMOTO and Shigeru HIRATA for supply of fossils in their collections.

IV. Note on the Distribution of *Daonella*

A great variety of *Daonella* is known from the Alpine-Tethyan geosyncline, while only 2 species occur from the "Binnensee" facies of the German Trias. These two species* of the Muschelkalk are according to TORNQUIST (1901) related to the Boreal and Californian fauna. In the Ladinic stage limestone and dolomite are extensive in the Alpine facies, whereas clastic sediments are predominant in the Himarayas and South China.

With DIENER and KUTASSY's Catalogues it is known that some 14 Anisic, 35 Ladinic, 3 Carnic and 2 Noric species of *Daonella* occur in the Alps. In the East Alps is the Hallstatt facies whence 19 species of *Posidonia* but only 3 *Daonella* were reported by MOJSISOVICS (1874). All of them were collected from the Carnic and Noric stages. In Aussee region near Salzburg the lower Carnic limestone bears *D. proboscidea* and *D. teltchenensis* beside 15 *Halobia*. *D. imperialis* is coexistent with 13 *Halobia* and 3 *Monotis* in the grey Noric limestone of Ischlana. *Imperialis* and *gosaviensis* are the only Noric *Daonella* in the East Alps. A light grey limestone of the Buchenstein stage in the Seewiesen region near Aflenz yields *moussoni* and its allies. In north Tyrol the Wengen horizon contains *tyrolensis*, *indica* and several other species of *Daonella*.

From the South Alps are reported 8 Anisic, 13 Ladinic and 1 Carnic species. The *Daonella* bed of the Buchenstein stage is represented by the *tarmelii* zone in the upper part where calcareous shales are intercalated in dark or black platy limestones. The *lommeli* bed lies in black or brownish grey sandy platy shale of the lower Wengen stage. The Cassian stage containing *kittli*, is represented by clayey, marly and calcareous sediments in addition to impure limestone and oolite layers.

In Lombardia the *Daonella* bed lies in the upper Esino-limestone which is composed of *lommeli*-bearing platy limestone. SALOMON (1895) described *lommeli*, *esinensis* and *parthanensis* from the Wengen stage of the Marmolata limestone. In south Tyrol several *Daonella* are contained in black marly Muschelkalk of of the Buchenstein stage. The Wengen stage of Wengen is indicated by *lommeli* and 3 *Posidonia*. The Cassian stage yields *kittli*, *richthofeni* and *H. fluxa*.

In Hungaria the Buchenstein stage or the *reitzi* zone is represented by the siliceous yellow limestone with intercalation of marl and contains 4 *Daonella* and 1 *Posidonia*. The Wengen or the *tridentinus* stage contains 10 *Daonella* ubiquitously. It is characterized by hard, red chert-bearing beds, passing upward into light violet marl and chert nodule-bearing light red limestone. Where chert nodule is absent, the red limestone looks like Hallstatt facies and contains cepha-

*) For TORNQUIST's *D. bergeri* KITTL (1912) proposed a new genus *Dipleurites* on the basis of two internal thickenings which run below umbo and are divided posteriorly. According to ICHIKAWA (1958) the thickenings are, however, not original but produced by the secondary modification, and he considers it a synonym of *Daonella*.

lopods. In Balaton lake distirict KITTL (1912) recognized 5 *Daonella* horizons in the Wengen stage above the *tarmelii* zone. They are *pichleri-bulogensis*, *loczyi*, *tripartita-indica*, *lommeli-Posidonia wengensis* and *reticulata* beds in ascending order. Several species of *Daonella* beside *Halobia* occur still higher in brownish limestone of the Cassian equivalent and an additional species of *Daonella* occurs in the white limestone of the Raibl equivalent.

In the Balkan Peninsula 5 *Daonella* are reported from the *lommeli*-zone or the Wengen stage of South Dalmatia where *Daonella* beds are represented by calcareous or sandy shale in tuff and tuffaceous sandstone (ARTHABAR, 1915)-*D.* cfr. *parthanensis* and *D.* cfr. *kittli* are the Cassian elements in the dark shale. In the superjacent formation tuffaceous sediments are replaced by cherty rocks, where *styrica* and others occur. In Bosnia the lower Ladinic stage is built up by red noduliferous limestone, in the middle part of which melaphyre tuff and tuffaceous sandstone containing *lommeli* are intercalated; marl and platy limestone with *pichleri* is found in the upper. Carnic *styrica* is known from the red Hallstatt facies of its middle part. In Greece *kittli* is known in the platy limestone and chert, and *styrica* in the cherty facies (RENZ, 1906). As DIENER (1915) stated, the Alpine Ladinic on the whole is characterized by limestone and dolomite complex.

A few *Daonella* are known from Afganistan and Jordan Valley (COX, 1924). In the Himalaya the Ladinic black limestone with shales yields *lommeli*, *indica* and *spitiensis*.

In Yunnan yellowish or greenish sandstone and shale in alternations are superior to bituminous or muddy limestone. These rocks yield one species of *Daonella* and 4 of *Halobia* besides several other pelecypods and cephalopods. *Daonellae* are known from Kweichow, Kwangsi and Hunan (Compilalation Committee etc., 1958). Light coloured muddy or shaly deposits are developed in west Kweichow and grey limestone, 10–20 m thick in the lower part, yields 3 species of *Daonella*, 4 of *Halobia*, 1 of *Posidonia*, *Protrachyceras* cfr. *archelaus*, other cephalopods, brachiopods and crinoids. In west Kwangsi variegate shales with yellow sandstone and limestone nodules contain 5 species of Anisic *Daonella* beside several other mollusks. They are *moussoni*, *dubia*, *lindströmi*, *elongata* and *producta*, where the last is Hsü's (1940) new species, closely related to *elongata*. In east Hunan the Ladinic formation is composed of purplish yellow shale, sandstone and light grey limestone in alternation which contain *D. lommeli* and other fossils. Two species of *Daonella* are found from Thailand; one is Carnic *sumatrensis* in the greenish grey clayslate in the tributary of Khlong Mak near Malayan Border and the other an indeterminable form of *Daonella* (ex. gr. *pichleri*) in the clayslate from Lampang.

A *Daonella* bed in Sumatra is composed of clastic sediments and contains *kittli* and *sumatrensis* in shale (VOLZ, 1899). It is equivalent to the Raibl. In Timor *Daonella* is common in the so-called "*Halobia* facies" from Ladinic to Noric (KRUMBECK, 1922), which is composed of limestone, calcaleous shale, clayslate, marly shale, radiolarian-bearing chert and radiolarite (WANNER, 1956). They yield 4 species of *Daonella*, 24 of *Halobia* and 2 of *Monotis* beside some pelecypods and brachiopods. These Ladinic species of *Daonella* are *indica*, *lilintana*, cfr. *bulogensis* and *pichleri* var. *timorensis*. They occur also in the flysch facies composed of light coloured limestone, calcareous or siliceous shale with or without clay matter. Cherty materials are recognized as interstitial deposit as well as bed-forming materials. WANNER (1956) considered them to be auto-

chthonous. The "cephalopod-facies" contains a copious fauna including many upper Ladinic fossils, but *D.* cfr. *bulogensis* is a rare lower Ladinic element. In Portuguese Timor another horizon, probably of the Cassian stage, is represented by *D.* aff. *kittli* and *D. indica* from siliceous limestone. These fossil beds are related to the Hallstatt deposits in fossils as well as lithology, and form Decken. From Rotti, ROTHPLETZ (1892) reported *lommeli* and *kittli* beside 3 species of *Halobia* and a *Monotis*.

In New Zealand exist two *Daonella* beds in south island. One is in the Anisic Etalian stage and the other in the Ladinic Kaihikuan stage. TRECHMANN'S (1917) *indica* from the latter is known now by the name of *apteryx* MARWICK For the *Daonella* beds (1953). in south Ussuri the reader is referred to page 7.

In California and Nevada there are 5 species of *Daonella* beside many ammonites of Middle Trias. According to SMITH (1902) the fauna is related to the Boreal as well as Tethyan fauna but not the Indian one. According to DIENER (1915) and TORNQUIST (1901) the faunas are closer to the Boreal than the Tethyan. Recently ZEIL found the Middle Triassic from Chile, in which *D.* ex gr. *lommelisturi* was included (ICHIKAWA in ZEIL, 1958). This fossiliferous bed is composed of conglomerate, sandstone and shale.

Finally the Anisic "Daonellenkalk" and the Ladinic "Halobienkalk" are known in Spitzbergen. The former is composed of black, marly calcareous shale containing thick limestone lenses and nodules. These black limestones are rich in *D. lindströmi* and *D. arctica* besides 20 ammonites. BÖHM reported *D. loveni* from the Carnic of Bear Island.

Table: *Daonella* from the Zohoin Series

Localties / *Daonella* Species	Zohoin, Sakawa	Okazaki-goe	Ino		Sakuradani Area					
								Usugatani		
			Kuroiwa	Koretomo	Semidani	Junisha	Gorodani	Makiodani	Koyanomizo	Tsuzurazaka
tenuistriata	r	–	–	–	–	–	–	–	–	–
alta	R	–	–	–	–	–	–	–	–	–
indica	c	–	c	c	–	c	r	c	c	c
cfr. *spitiensis*	r	–	–	–	–	–	–	–	–	–
iwayai	r	–	r	–	–	–	–	–	r	c
kotoi	c	–	c	c	r	–	–	–	r	c
kotoi var.	–	–	c	–	–	–	–	–	–	–
sakawana	R	–	r	–	–	–	–	–	–	–
subquadrata	a	?	c	c	–	c	–	c	c	r
subquadrata zohoinensis	a	r	c	c	–	c	–	–	–	–
subquadrata symmetrica	a	–	–	–	–	c	?	c	R	–
pectinoides	r	–	–	–	–	–	–	–	c	–
asymmetrica	r	–	–	–	–	–	–	–	–	–
hiratai	r	–	–	–	r	–	–	–	–	–

a: abundant, c: common, R: rare, r: very rare

It is remarkable that more than 70 forms of *Daonella* are limited to occur in the Alpine-Tethyan geosyncline. Therefore *Daonella* can be said a characteristic pelecypod of the pelagic geosynclinal facies. From the Alpine region approximately 50 forms of *Daonella* are reported. In the Circum-Pacific region, on the other hand, *Daonella* is rather poor and the *Daonella* beds are mostly clastic rather than calcareous. This must be related to the older Mesozoic crustal movement which is known in Japan by the name of Akiyoshi orogeny. It culminated in the Ladinic and Carnic ages. The Alps, where calacareous facies is predominant, was quiet in these ages except a part of the East Alps. Clastic sediments become predominant in the Himalayan and Pacific geosynclines, and cherty facies is often met with in *Daonella* beds in Southeastern Asia.

Both *Daonella* and *Halobia* range from Anisic to Noric, and *Daonella* was flourished in the Ladinic and *Halobia* in the Carnic. The Wengen and Cassian stages are the transition from the *Daonella*-age to the *Halobia*-age. The Buchenstein stage yields more *Posidonia* than *Daonella*. and almost free from *Halobia*. In Himalaya the *lommeli* zone comprises 4 forms of *Daonella* and 3 of *Halobia*. According to ROTHPLETZ *lommli* and *kittli* are coexistent with 3 species of *Halobia* in Rotti. Therefore *Halobia* kept up in the Cassian with *Daonella*. In the Raibl or the *aonoides* zone *Halobia* was already superior to *Daonella*. In Sumatra the *Daonella* bed yields 4 species of *Halobia* and 2 of *Daonella*. In Misol the Ladino-Carnic Keskaïn formation comprises *D. lilintana* and 4 forms of *Halobia*. In the Salzburg Alps 2 lower Carnic forms of *Daonella* and 15 of *Halobia* are coexistent. In Japan *Daonella* and *Halobia* beds are isolated except for the Atsu series, in which *D. yoshimurai* is coexistent with more numerous individuals of *Halobia* in 2 species.

V. Description of *Daonella* in Japan

Genus *Daonella* MOJSISOVICS

1874: *Daonella* MOJSISOVICS, *Jb. k. k. geol. R.-A., Bd. 7, Heft 2*, S. 6.

The *Posidonia*-like stage seen in many species of *Daonella* and also *Halobia* in their umbonal regions shows their derivation from *Posidonia* as generally accepted. It is quite probable that *Halobia* was evolved from *Daonella* by the development of the anterior ear, almost simultaneously with the appearance of the latter genus. Their life ranges are from Anisic to Noric, but the acme was Ladinic for the latter and Carnic for the former. This agrees with the frequency of their occurrences in Japan.

KITTL erected *Enteropleura*, *Dipleurites* and *Amonotis* as three new genera of the Halobiidae. In his recent revision ICHIKAWA (1958) divided the family into the Halobiinae and the Aulacomyellinae (nov.). While he synonymized *Dipleurites* with *Daonella* s. str., he recognized *Enteropleura* as well as *Veldinella* ALMA as two subgenera of *Daonella*. As to *Amonotis*, he suggested its possibility to be a member of the latter subfamily.

In 1874 MOJSISOVICS has classified 26 species of *Daonella* into 3 groups as follows:

1. Gruppe der *Daonella moussoni*: nächst den Schloßrändern keine Rippen.
2. Gruppe der *Daonella tyrolensis*: Rippen nicht gebündelt, bis zu den Schloßrändern reichend.

3. Gruppe der *Daonella lommeli*: Rippen gebündelt.

Later in 1912 KITTL reclassified the genus and 57 species were schematized into 8 groups as follows:

1. Die Gruppe der posidonoiden Formen, die nur eine schwache Radialskulptur besitzen, mit drei Untergruppen;
   a) Untergruppe der *Daonella böckhi*.
   b) Untergruppe der *Daonella proboscidea*.
   c) Untergruppe der *Daonella gosaviensis*.
2. Die Gruppe der *Daonella moussoni* mit schwächerer, oft nur in der Schalenmitte deutlicher Radialskulptur.
3. Die Gruppe der *Daonella tyrolensis* mit deutlichern Radialrippen, welche gewöhnlich eine ein- bis zweimalige Spaltung zeigen und meist bis zu den Schloßrändern reichen.
4. Die Gruppe der *Daonella sturi* und *Daonella lommeli* mit Bündelrippen und von querverlängerter Gestalt.
5. Die Gruppe der *Daonella grabensis* mit feinen, nicht oder undeutlich gebündelten Rippen.
6. Die Gruppe der *Daonella pichleri* mit weit vorgerücktem Wirbel.
7. Die Gruppe der *Daonella lamellosa*, durch vorwiegend konzentrische Skulptur der Schale ausgezeichnet.
8. Isolierte und dubiose Formen.

In the Triassic of Japan there are 14 species of *Daonella*, in addition to 2 subspecies namely, 2 species from the Rifu series, 11 species plus 2 subspecies from the Zohoin series and 1 species from the Atsu series which are classified according to KITTL's scheme as follows:

Group of *moussoni*
- *Daonella atsuensis* KOBAYASHI ..... Atsu Series
- ? *Daonella tenuistriata* KOBAYASHI & TOKUYAMA, n. sp. ..... Zohoin Series

Group of *tyrolensis*
- *Daonella alta* YABE & SHIMIZU ..... Zohoin Series
- *Daonella indica* BITTNER ..... Zohoin Series
- *Daonella* cfr. *spitiensis* BITTNER ..... Zohoin Series
- *Daonella iwayai* KOBAYASHI & TOKUYAMA, n. sp. ..... Zohoin Series
- *Daonella kotoi* MOJSISOVICS ..... Zohoin Series
- *Daonella sakawana* MOJSISOVICS ..... Zohoin Series

Group of *sturi-lommeli*
- *Daonella subquadrata* YABE & SHIMIZU ..... Zohoin Series
- *Daonella subquadrata zohoinensis* KOBAYASHI & TOKUYAMA, n. subsp. ..... Zoeoin Series
- *Daonella subquadrata symmetrica* KOBAYASHI & TOKUYAMA, n. subsp. ..... Zohoin Series
- *Daonella multistriata* YABE & SHIMIZU ..... Rifu Series
- *Daonella densisulcata* YABE & SHIMIZU ..... Rifu Series

Group of *grabensis*
- *Daonella pectinoides* KOBAYASHI & TOKUYAMA, n. sp. ..... Zohoin Series

Group of *pichleri*
- *Daonella asymmetrica* KOBAYASHI & TOKUYAMA, n. sp. ..... Zohoin Series
- *Daonella hiratai* KOBAYASHI & TOKUYAMA, n. sp. ..... Zohoin Series

Group of *D. moussoni*

1. *Daonella yoshimurai* KOBAYASHI

MM3472-3-2

Plate III, figure 2

1935. *D. yoshimurai* KOBAYASHI, *J.J.G.G., Vol. 12*, p. 30, pl. 7, fig. 7.

This species is characterized by semi-circular outline, but broadest shortly

below hinge, subtriangular smooth subhinge area and broad flattopped ribs, 7–10 in number and bifurcated in later stages. Caused by lateral compression, a small left valve (MM 3472) from a point some 150 m SW from the type locality swells up, and is taller than broad; anterior area larger than posterior one.

Comparison:—This is undoubtedly a member of KITTL's *moussoni* group, but no species of the group is very close to it. Ladinic *paucicostata* TORNQUIST differs from it in more prominent umbo, more numerous ribs and narrower posterior subhinge area. Ribs are more numerous and the outline is longer in *udvariensis* KITTL from the Ladinic of Bakony. Finally, Carnic *sumatrensis* VOLZ is similar to it in the wide area, number and more of ribbing, but mode inequilateral.

Occurrence:—Scattered in black shales in the upper Atsu series. At a point north of Shirogawara it is associated with *Halobia atsuensis*, *H. subsedaka* and *Oxytoma atsuense* (TOKUYAMA, 1959) in a shaly bed in the alternation of coarse sandstone and black shale. *Halobia* is more common than *Daonella* in the shales. Here a sandy intercalation yields lower Carnic *Minetrigonia katayamai*.

2. *Daonella tenuistriata* KOBAYASHI and TOKUYAMA, new species

Plate III, figure 10 ✓ MM3473-3-10

Description:—Shell almost as high as wide, somewhat diagonal. Hinge line straight, forming obtuse angles at ends. Umbo median, prosogyrous. Ribs numerous, flat-topped, regularly bifurcated in antero-median to postero-median part; median and postero-median ribs often twice bifurcated. Posterior smooth area large. Concentric wrinkles distinct in early stage. In the *Posidonia*-like stage which is relatively long lasting, the shell is prolonged diagonally and wider than high. Then wide and flat-topped ribs appear in the median part which become successively bifurcated. Subsequently this ribbing extends anteriorly. The outline becomes relatively tall and more equilateral in grown stage.

Observation:—A specimen at hand (MM 3473) is an internal mould of open valves, 15.1 mm high and 15.9 mm wide. Ribs are flat-topped in the immature stage. In the anterior part the aspect is maintained until the maturity. Many ribs in the adult stage are bi- or quadri- furcated. Though the posterior part is partly broken, it is certain that it has a large smooth posterior area.

Comparison:—It is related to KITTL's second group in growth change, but in the group ribs are generally weak, often flattopped and rare on the lateral parts. In this species, on the other hand, ribs maintain their significance, though fine, as far as the anterior hinge. Two areas are present, commonly wider in anterior in *moussoni* and *udvariensis*. In the disappearance of posterior ribs this agrees with *pectinoides* but the ribs are simple, round-topped in that species. In once or twice bifurcation of all ribs it resembles *arzelensis* or KITTL's third group, in which, however, the areas are ill-developed and the posterior one is never wider than the anterior one.

Occurrence:—Rare at Zohoin in Sakawa.

Group of *D. tyrolensis*

3. *Daonella alta* YABE and SHIMIZU

Plate I, figures 4, 5 ✓ MM3476-1-4 MM3474-1-5

1927. *D. kotoi* var. *alta* YABE & SHIMIZU, *Sci. Rept. Tohoku Imp. Univ. Vol. 11*, p. 122, pl. 12, fig. 10.

Description—Shell subequilateral, somewhat wider than high. Hinge short and rounded at ends. Umbo submedian, prosogyrous. Ribs about 20, flat-topped, wide in median part and narrowing laterally; primary grooves relatively wide and rounded on bottom; secondary grooves starting at about 1 cm from umbo; antero-median ribs sometimes trifurcated; some ribs twice bifurcated in grown stage; posterior ribs sometimes arcuate. Concentric wrinkles fairly distinct near umbo. In *Posidonia*-like stage shell wide and more oblique than in later stages; hinge line relatively long. Then primary ribs suddenly appear in whole breadth.

Observation:—Two specimens of the present collection (MM 3475, 77) agree with the holotype in relatively small size and straight ribs, but the ribs are arcuate in another two larger specimens (MM 3474, 76). They are more or less irregular in the postero-median part in the holotype and also the former two, while in the latter two they are regular (pl. 1, figs. 4, 5). Likewise *D. indica* comprises two forms with straight and arched ribs (BITTNER, 1889, KRUMBECK, 1924). The ratio of width to height varies 1.2–1.5.

Comparison:—This was first considered a high variety of *D. kotoi* but distinct from *kotoi* in the equilateral outline, wide and regular ribs and distinct interspaces. These aspects suggest closer relationship to *tyrolensis* or *indica*. Compared to *tyrolensis* its ribs are somewhat stronger and less numerous.

Occurrence:—Zohoin at Sakawa.

MM3495-1-1
MM3478-1-2
MM3486-2-1
MM3480-2-2
MM3528-3-3
MM3539-3-4
MM3540-3-11
MM3531-3-12
MM3485-4-1

4. *Daonella indica* BITTNER

Plate 1, figures 1, 2; plate 2, figures 1, 2; plate 3, figures 3, 4, 11 & 12; plate 4, figure 1

1899. *D. indica* BITTNER, *Pal. Ind., ser. 15, vol. 3*, p. 39, pl. 7, figs. 4–11.
1907. *D. indica*, WANNER, *N. Jb, Min. usw. 24. B.-Bd.*, p. 202, pl. 9; figs. 8, 9, pl. 10, figs. 2, 3.
1908. *D. indica*, DIENER, *Pal. Indica, ser. 15, vol. 5*, p. 11, pl. 3, figs. 6, 7, 10.
1912. *D. indica*, KITTL, Halobiidae usw., p. 48, pl. 4, figi. 10, 11; pl. 9, fig. 2.
1915. *D. indica*, v.ARTHABER, *Beitr. Geol. Pal. Österr.-Ungarns usw., Bd. 27*, S. 191.
1927. *D. indica*, REED, *Pal. Indica, NS. vol. 10*, p.194, pl. 17, fig. 4.
1930. *D. indica*, KUTASSY, *Földt. Közlöny, Bd. 60*, p. 203, pl. 3, fig. 1.

Description:—Shell rounded, subequilateral, as high as wide. Hinge line short, straight forming obtuse angles with anterior and posterior margins. Umbo median, rounded, slightly projected above hinge. Ribs about 35–50, distinct, flat-topped regularly bifurcated, mostly equal in strength and distributed on whole surface, but become finer near hinge margin. Concentric wrinkles distinct in young. Outline apparently narrower in *Posidonia*-like stage.

Observation and comparison:—In this species ribs are mostly straight, but the median ones are arcuate in two specimens (MM 3478, pl. 1, fig. 2; MM 3492). They are commonly of equal strength and bifurcated regularly on the whole surface, but sometimes become narrower laterally. In another two specimens (MM 3490, 91) a narrow smooth triangular area is seen near the posterior hinge margin. Still another specimens (MM 3495, pl. 1, fig. 1; MM 3539, pl. 3, fig. 4) show irregular trifurcation in the antero-median part.

Daonella indica occurs in Anatolia, Himalaya (BITTNER), Spiti (DIENER), Yunnan (MANSUY), Kweichow (LEE et al.) and Timor region (WANNER, KRUMBECK, KUTASSY) in Asia and the East Alps, Dinaric Alps, Hungaria, and Dalmatia in Europe

(KITTL, ARTHABER). Asiatic specimens bear relatively strong ribs of equal strength on the whole surface as seen on the Himalayan and Timor examples. DIENER's from the *Daonella*-limestone in the west of Lilang also bears fairly distinct straight ribs, but they become weakened toward the hinge. In KITTL's specimen from the Alps they are weaker than in Spiti specimens and become weaker laterally. These European forms resemble *bulogensis* or *tyrolensis*. As above described, Japanese specimens have strong and regular ribs on the margin like the other Asiatic specimens. Compared to the foreign specimens, they are relatively small and bear more ribs. Sakuradani specimens (pl. 3, fig. 3) have numerous and fine ribs, while wide-ribbed (MM 3478, pl. 1, fig. 2) as well as narrow-ribbed (MM 3483) specimens are in Zohoin collection.

In the regular bifurcation *indica* belongs to KITTL's *tyrolensis* group. It agrees with *tyrolensis* MOJSISOVICS, *bulogensis* KITTL, *arzelensis* KITTL's, *lóczyi* KLTTL, *spitiensis* and *lilintana* BOEHM in the tall, equilateral outline and regularly bifurcated ribs. In *indica* most ribs are equal in strength and width and the smooth area near the hinge is either absent or very narrow. The last feature is seen also in Asiatic *spitiensis* and *lilintana*.

Occurrence:—Common through all localities of the Zohoin series in Sakawa, Ino and Sakuradani regions. Sakawa and Sakuradani collections include wide-ribbed and narrow-ribbed forms; most of Ino collection immature. Sakuradani specimens from Junisha, Gorodani and Makiodani, Koyanomizu, Tsuzurazaka in Usugatani, all in the Fujinohira Decke, are deformed by lateral compression in similar manner.

5. *Daonella* cfr. *spitiensis* BITTNER

Plate I, figure 3. MM3496-1-3

1899. cfr. *D. spitiensis* BITTNER, *Pal. Ind., Ser. 15, Vol. 3*, p. 38, pl. 7, fig. 3.

Description:—Shell rounded, eqnilateral, almost as high as wide. Umbo small, median, pointed; hinge short, remarkably rounded at extremities. Ribs about 40, most pronounced at middle, weakened laterally till at last a narrow smooth area appears on each side; median ribs finer on anterior than on posterior side and bifurcated or even trifurcated. Concentric wrinkles distinct in early and middle stage. Young shell relatively high.

Observation and comparison:—An imperfect internal and external mould of a left (?) valve (MM 3496) resemble BITTNER's *spitiensis* closely in the well rounded outline and mode of ribbing, but it is higher and its ribs are more distinct. It is distinguishable from *indica* by its more rounded lateral angles and more developed non-ribbed area.

Occurrence:—Rare at Zohoin in Sakawa.

MM3498-2-15
MM3497-3-8
MM3481-3-9
MM3537-4-4

6. *Daonella iwayai* KOBAYASHI and TOKUYAMA, new species

Plate II, figure 15; plate III, figures 8, 9; plate IV, figure 4.

Description:—Shell a little higher than wide. Hinge line straight, subangular at ends; umbo mesial. Primary furrows about 25, wide and rounded on bottom, while primaly ribs are flat-topped, once or twice bifurcating; secondary ribs in median part provided with 2 or 3 fine tertiary furrows, so that they look like

bundle ribs; tertiary furrows become uncommon toward hinge, but each inserted regularly on a secondary rib in the median part; ribs weakened or effaced near hinge where smooth triagnular areas appear, posterior one being larger than anterior. Concentric wrinkles distinct near umbo.

Observation:—Caused by lateral compression, the holotype (MM 3497) from Tsuzurazaka in Usugatani (pl. 3, fig. 8) is prolonged. Judging from two imperfect specimens from Tosa, the underformed outline of this species may be nearly as wide as high. In the median part of the holotype 2 tertiary furrows are preserved on a secondary rib. In a Zohoin specimen (MM 3498, pl. 2, fig. 15) which is large but fragmentary, furrows of three orders are all rounded on bottom; the primaries about 4 times as wide and as deep as the secondaries, which the latters again are 3 to 4 times as wide and as deep as the tertiaries; a secondary rib bears commonly 2 to 3 tertiary furrows and 4 at maximum. The Kuroiwadani specimen from Ino (MM 3481, pl. 3, fig. 9) which is also large but fragmentary, represents fairly regular twice bifurcation.

Comparison:—In ribbing this is closely related to *bulogensis* KITTL, especially to cfr. *bulogensis* from Timor by KRUMBECK. In this species, however, the primary ribs are never trifurcated as those allies; its outline is higher and more equilateral. In the bundles of ribs the two large imperfect specimens are remarkably similar to *lommeli*, especially to one from Bithynia (ARTHABER, 1915), although the outline is not equilateral and not so high as in this species. *Arzelensis* KITTL from the upper Ladinic Wettersteinkalk of Innsbruck is more or less equilateral and its large form higher than wide. Its outline, position of umbo, hinge extremities and subhinge area accord with those of this species but the ribbing is more regular in this than in KITTL's.

Occurrence:—Common at Tsuzurazaka in Usugatani, Sakuradani in Awa, one specimen is collected from Kuroiwadani near Ino and two more from Zohoin, Tosa. The Holotype collected from Tsuzurazaka.

MM5001-2-3
MM3487-2-4
MM3488-2-5
MM3489-2-6
MM3503-3-1
MM3504-4-2
MM3505-4-3

7. *Daonella kotoi* MOJSISOVICS

Plate II, figures 3–6; plate III, figure 1; plate IV, figures 2, 3.

1888. *D. kotoi* MOJSISOVICS, *Beitr. Österr.-Ungarns usw. Bd. 7*, S. 174, Taf. 2, Fig. 3.
1912. *D. kotoi*, KITTL, Halobiidae usw., S. 74.
1915. *D. kotoi*, ARTHABER, Lethaea Geognostica, II–1, S. 191, Taf. 31, Fig. 1.

Description:—Shell medium to large in size, inequilateral, obliquely ovate and longer than high. Hinge line straight and rounded at ends. Umbo prosogyrous, at about 2/5-length from anterior extremity and acuminate a little above hinge. Primary ribs about 30, distinct flat-topped, becoming narrow and irregular backward; median ribs often bifurcated and rarely trifurcated; concentric wrinkless more or less distinct. Three stages of growth can be distinguished as follows:

1. *Posidonia*-like stage: smaller than 3 mm long and 2.5 mm high (MM 3489, pl. 2, fig. 6; 3549), round, convex, with concentric growth lines and without radial markings.
2. *Moussoni*-like stage (MM 3489, pl. 2, fig. 6): about 3–7.5 mm long 2.5–5 mm high, roundly ovate; several narrow and weak radial grooves start at first in median part, successively added on posterior side; ribs narrower in posterior than median part.

3. Adult stage: shell 5 cm long and 3 cm high at the maximum (pl. 2, fig. 3, holotype, MM 3001), longer than high and more diagonally elongated than in young stages; ribs cover whole surface, uniform in strength, of same width in antero-median part and slightly narrow on posterior side, where secondary grooves are absent or 2 secondaries are inserted on a primary rib. They start at first in the median part (MM 3489, pl. 2, fig. 6), occur in anterior in the next and finally on the posterior side.

Observation:—The outline is variable in this species to some extent. Length/height ratio and obliquity are commonly greater in some Zohoin specimens than the holotype. The beak happens to be submedian on hinge (MM 3503, pl. 3, fig. 1). The mode of ribbing is variable. In some specimens (MM 3488, pl. 2 fig. 5) secondary grooves are indiscernible in the antero-median part as in the holotype, but distinct in others. The ribbing is fairly regular in some but in some others it is irregular in strength and width in posterior.

Comparison:—MOJSISOVICS included this species in the *tyrolensis* group, while did KITTL in the *sturi-lommeli* group. In the simple ribbing it may be included in the former group. However, if its growth change is considered, it is related to the *moussoni* group. *Daonella paucicostata* TORNQUIST from the Ladinic of the South Alps and Dinaric Alps is close to it. In the growth change, ribbing and antero-dorsal aspect *paucicostata* fits in it. MOJSISOVICS' is, however, a little more oblique and ribs are more or less stronger than TORNQUIST's. *D. apteryx* MARWICK from New Zealand is another close ally, but has more ribs. In outline and ribbing this species resembles *D. kittli* KRUMBECK from the Carnic of St. Cassian, which, however, is distinguishable from it by the second growth stage when, according to KITTL, grooves start at once in the entire shell in *kittli*, while in this they start at first in the median part.

Occurrence:—Common in Zohoin and Ino in Tosa and Tsuzurazaka in Sakuradani regions, but rare in Semidani. At Koretomo and sometimes at Sakawa small shells are crowded.

Daonella kotoi MOJSISOVICS var.

Plate II, figure 7

MM3507-2-9

Description:—Shell more or less obliquely elongated; anterior angle of hinge line subrounded; umbo in anterior or hinge line prosogyrous, Ribs wide, flat-topped, sometimes flexiated, appearing first in median part, regularly trifurcated there and bifurcated on sides. Concentric wrinkles present in umbonal region.

Observation and comparison:—Three specimens at hand (MM 3507/1-3) are all imperfect. In the oblique outline and regular trifurcation of the median ribs this form resembles BITTNER's cfr. *indica* from Pin valley in Spiti (1889, pl. 7, fig. 12), which was referred to cfr. *bulogensis* KRUMBECK, although its trifucation is more regular. Among Japanese species *kotoi* is most intimate to this, except for the regularity of trifurcation.

Occurrence:—Not rare at Kuroiwa, near Ino, Tosa.

8. *Daonella sakawana* MOJSISOVICS

Plate II, figure 8.

MM5002-2-8

1888. *D. sakawana* MOJSISOVICS, *Beitr. Pal. Österr.-Ungarns usw.*, *Bd. 7*, S. 174, Taf. 2, Fig. 4 (non Fig. 5).

1912: *D. sakawana*, KITTL, Halobiidae usw., S. 74.

Description:—Shell medium in size, inequilateral, obliquely ovate, wider than high. Umbo prosogyrous, pointed above hinge at anterior 2/5; hinge straight, relatively short, forming an obtuse angle with anterior margin. Ribs about 40, distinct, regular, flat-topped, usually bifurcated, uniform in width in median part, narrowing towards hinge; in antero-median part a fairly stronger groove inserted in every 3 or 4 primary ribs. Concentric wrinkles fairly distinct, closely spaced in earlier stage and widely later. Outline high and less inequilateral at the beginning, becoming relatively low and more obliquely elongated. In consequence adult shells look more inequilateral than young ones.

Observation:—MOJSISOVICS' type specimens include 2 species. One (pl. 2, fig. 9, MM 5003) is specifically distinct from the other in fig. 4 (pl. 2, fig. 3, MM 5002) and belongs probably to *subquadrata zohoinensis*. A few fragmentary specimens in the present collection are identifiable with this species.

Comparison:—Originally, MOJSISOVICS included this species in his *tyrolensis* group, while KITTL referred it to his group of *sturi-lommeli*. The regular bifurcation of ribs on the whole surface suggests its being a member of the *tyrolensis* group, Cassian *kittli* KRUMBECK and *richthofeni* by BITTNER (1895) are especially similar to but different from it in the second growth stage, in which they have ribs on the entire surface, because in this species ribs appear only in the median part. In other words it grows through *moussoni*-like stage as *kotoi*. It differs from *kotoi* in its denser and more regular ribs. The anterior end of the hinge is rounded in *kotoi*, but angled in this; ribs are more or less rounded in it but flat-topped in *kotoi*.

Occurrence:—Relatively rare at Zohoin, Sakawa and at Kuroiwadani, Ino.

Group of *D. sturi-lommeli*

9. *Daonella subquadrata* YABE and SHIMIZU

1915. *D. sakawana*, DIENER, *Denkschr. k. Akad. Wiss., Wien, Bd. 92*, S. 25, Taf. 1, Fig., 3; Taf. 2, Fig. 5.

1927. *D. densisulcata* var. *subquadrata* YABE & SHIMIZU, *Sci. Rept. Tohoku Imp. Univ. Sec. 2, Vol. 11*, p. 122, pl. 22, fig. 9.

Description:—Shell large; outline considerably variable from obliquely elongated, highly inequilateral, to high, equilateral form. Umbo median or a little anterior, sharp, obtusely angled at anterior end but rounded at posterior end. Ribs fine, about 60, round-topped, distributed on whole surface, wider in posterior than anterior side, regularly bifurcated in anterior and antero-median parts, trifurcated in median part and irregularly trifurcated in posterior. Concentric wrinkles fairly distinct. In *Posidonia*-like stage (MM 3553; 3514, pl. 3, fig. 5), shell diagonally ovate, wider than high, with prominent, large and prosogyrous umbo; in the succeeding stage (pl. 2, fig. 10), flat-topped simple ribs start in anterior and median parts and suddenly bifurcated; ribbing successively extended over whole breadth; simultaneously, outline becomes subquadrate or trapezoidal. Then shell growth diverges in three trends; outline elongated diagonally and tending more inequilateral in one; shell becomes taller and almost equilateral in another; still another form to which the holotype belongs, is intermediate. Here are recognized the following 2 subspecies beside the typical form:

a) *Daonella subquadrata zohoinensis* KOBAYASHI and TOKUYAMA, new subspecies.
Plate I, figures 12, 13; plate II, figure 9; plate III, figure 5.

Shell ovate or subelliptical, diagonally elongated, strongly inequilateral. Umbo at anterior 1/3 to 2/5 of hinge. Sometimes shell more elongated posteriorly than diagonally (MM 3511, pl. 1, fig. 13; MM 3512, [illegible], but some others has the prolonged postero-median part (MM 3510, pl. 1, fig. 12). Shell is usually wider than high.

b) *Daonella subquadrata* YABE & SHIMIZU (s. str.)
Plate I, figures 6, 7; plate II, figures [illegible], 10.

Shell roundly ovate, almost as high as wide. This is suboval and wider than high in *Posidonia*-stage (MM 3518), but trapezoidal or subquadrate in later stages (MM 3521, 23, 24). Finally, it tends to be prolonged postero-ventrally (MM 3516, pl. 2, fig. 6).

c) *Daonella subquadrata symmetrica* KOBAYASHI & TOKUYAMA, new subspecies
Plate I. figures 8–11.

Shell equilateral, higher than wide. This also grows through the suboval and subquadrate stages but short and the outline is high already in immature stages. Subsequently the height increase greatly.

Observation:—The large shells are often met with in typical *subquadrata* (pl. 1, fig. 6). Strength and density of ribs are almost same through the surface. In the full-grown examples (MM 3510, 16.) bi- or tri-furcated ribs are again bifurcated (pl. 1, figs. 6, 12). In case of tri-furcation ribs are sometimes divided so unequally that a secondary rib happens almost twice as wide and as strong as another. Grooves on the bundled ribs are narrower than every secondary rib. The bundles in this species are produced regularly by bi- and tri-furcation in later stages, whereas ribs of KITTL's 4th group such as of *sturi*, *lommeli* etc. are "bundle-ribs" already at the beginning.

Comparison:—This was originally described by YABE and SHIMIZU as a variety of *densistriata* from the Rifu formation. *Densistriata*, however, widely differs from this in outline and mode of ribbing. Namely, *densistriata* is more or less convex and much wider than high; the ratio of width/height is smaller in early stage and becoming larger through growth, while the growth change is reverse in *symmetrica*. The ribs in *densistriata* are flat-topped, widest in the median part, and narrow laterally, especially posteriorly; but in this species they are round-topped, uniform in width and strength, and regularly bi- or trifurcated.

Daonella lilintana BOEHM from west Misol is the closest ally to this species, especially to *symmetrica*. This subspecies is identifiable with *lilintana*, if irregular bifurcation of ribs in *lilintana* are ignored. In KRUMBECK's *lilintana* from Keskaïn island, ribs are generally weak, widest at the median part, a little narrow and obscure toward the hinge till a narrow triangular smooth area is formed. If *lilintana* of the two islands can safely be identified, *symmetrica* is separable from *lilintana* in the specific rank. This and *lilintana* belong to the same group with *indica* (KITTL, 1912). In KITTL's 4th group some species have no typical bundle-rib of *sturi*, for example, *longovarica* KITTL or *gaderana* KITTL. They resemble this in ribbing, but differ in the smooth area near the hinge.

Occurrence:—Abundant in the Zohoin series. *Subquadrata* (s. s.), *zohoinensis* and *symmetrica* are all well represented in the Zohoin collection. Poor impressions of *subquadrata* occur at Okazakigoe. Kuroiwadani collection includes many *zohoinensis* and several *quadrata*, but no *symmetrica*, while in the Sakuradani collection *symmetrica* is common and *zohoinensis* is absent except at Naise in Junisha.

10. *Daonella multistriata* YABE and SHIMIZU

Plate III, figure 7.

1927. *Daonella kotoi* MOJSISOVICS var. *multistriata* YABE & SHIMIZU, *Sci. Rept. Tohoku Imp. Univ., Ser. 2, Vol. 11, No. 2*, p. 123, pl. 11, figs. 12, 13.

This is specifically distinct from *kotoi*. It is related closer to *americana* SMITH or *dubia* GABB than *kotoi*, because *kotoi* belongs to KITTL's *tyrolensis* group, but this is a member of the *sturi-lommeli* group, to which *americana* and *dubia* also belong. In *multistriata* ribs in the median part are wide, flat-topped and irregular, but become weak laterally; fine ribs in postero-ventral to posterior side effaced in distinct triangular subhinge area; anterior ribs a little stouter and more distinct than posterior ones. *Kotoi* is characterized by ribs which are flat-topped, fairly regular, bifurcated, approximately of the same width from anterior to postero-ventral part; moreover the triangular smooth subhinge area is absent in *kotoi*.

Occurrence:—Rifu.

11. *Daonella densisulcata* YABE and SHIMIZU

1927. *Daonella densisulcata* YABE and SHIMIZU, *Sci. Rept. Tohoku Imp. Univ. Vol.* 11, No. 2, p. 125, pl. 11, fig. 13. (non pl. 12, figs. 8, 9)

1954. cfr. *D. densisulcata*, KIPARISOVA, Field illustrated Atlas etc. p. 27, pl .18, figs. 7, 8.

Daonella densisulcata is closely allied to "*moussoni*" by SMITH though different from typical *moussooi* from the Alps, because ribs are distinct, more or less irregular and sometimes flexiated in this and SMITH's, while, they are weaker, simpler and regular in typical *moussoni*. Nevertheless, these three forms agree in more or less diagonally elongated outline and fairly wide, smooth, triangular subhinge area. YABE and SHIMIZU's specimen from Zohoin in pl. 12, figs. 8, 9 belong to *subquadrata*, from which it is distinct in its bundled ribs and fairly wide smooth subhinge area.

One of KIPARISOVA's (1954) *densisulcata* (fig. 8) bears more regular ribs and narrower flattened subhinge-area than the typical Rifu form. The other specimen (fig. 7) is more closely related to the *subquadrata*-group, because ribs are distinct through the surface and they are almost regularly quadrifurcated. Further, its outline is higher and less oblique than *densisulcata*.

Occurrence:—Rifu.

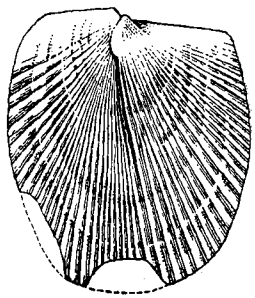
Group of *grabensis*

12. *Daonella pectinoides* KOBAYASHI and TOKUYAMA, new species

Plate II, figure 12; plate III, figure 6, Text-figure

Description:—Shell small, tall and equilateral. Hinge line longs, traight and subrectangular at extremities. Umbo small, bifurcated, round-topped,

widest in antero-median part; interspaces wide in anterior and narrow in anterodorsal; anterior triangular subhinge area fairly wide and non-ribbed, but marked with distinct concentric wrinkles. Juvenile shell fairly convex, equilateral, as high as wide, devoid of radial markings. In the second stage, ribs appear in median part, and then on lateral sides; outline sub-equilateral and as high as wide. In the third stage shell elongated posteroventrally and becoming higher than wide. Adult outline again equilatelal.



Text-figure: *Daonella pectinoides*; a diagonally compressed specimen showing the two manners of deformation.

Observation and comparison:—The holotype (MM 3532) is right internal mould, 13.2 mm. high and 11 mm wide. This spacies is related to the KITTL's 5th group. For example, *zellensis* KITTL from the Anisic of the North Alps and *subtenuis* KITTL from the Anisic of Bakony agree with it in shape, strength and density of ribs and width of posterior smooth subhinge area. It is, however, distinguishable from them by its high and equilateral outline.

Secondary deformation:—The junior author made an interpretation to the deformation of a laterally compressed left valve, MM 3533, from Usugatani in Sakuradani (pl. 3, fig. 6; Text-fig.). It is semielliptical and higher than wide; hinge line straight, subrectangular and rounded at extremities; ribs about 40, distinct simple, rounded on top and a few bifurcated. Its triangular, smooth and non-ribbed subhinge areas are narrower than in the holotype. Two kinds of deformation were produced on this specimen by the same stress from antero-dorsal to postero-ventral. The anterior part was deformed in harmony with surrounding medium of rock matrix, whereas the posterior part did not harmonize. Due to the compression rectangular to the stress its ribs were most narrowed in the antero-ventral part, while in the posterior part the ribs were modified not so much as between the hinge and ventral side. In non-deformed specimens, however, ribs are widest in the antero-dorsal part.

When stress operates a plastic body, it will be compressed in the trend of stress, but expanded rectangularly in case of equi-volume deformation. Therefore volume change is small or none in the anterior part of the shell. In another case, the deformation with volume change, the plastic body is simply compressed without rectangular expansion, as seen in posterior part of the shell, while the anterior part was probably deformed in the former manner at the beginning but later by the latter manner. In consequence the anterior part became longer than the posterior; in the former the density of ribs is considerably reduced near the hinge and in the ventral side, while the reduction is not so great in the latter. The median crack and the angle between the anterior and posterior hinge line show the difference between the two manners of deformation under the diagonal stress. It suggests that the compaction was incomplete when stressed.

Occurrence:—Rare at Zohoin in Sakawa and common at Tsuzurazaka and Makiodani in Usugatani in the Sakuradani region.

Group of *pichleri*

13. *Daonella asymmetrica* KOBAYASHI and TOKUYAMA, new species

Plate II, figure 13

MM3534-2-13

Description:—Shell small, roundly trapezoidal, diagonally elongated, widest shortly below hinge and nearly twice as long as high. Anterior and hinge margins form acute angle; antero-ventral margin rounded, passing into posterior one; posterior and postero-dorsal margins rounded. Beak prosogyrous, pointed above hinge at anterior third. Ribs about 30, stout, simple, rounded and widest in antero-median part, where interspaces are also wide, and finer in posterior than anterior side. Non-ribbed smooth triangular areas wider in posterior than anterior. Concentric wrinkles widely spaced. Smooth juvenalium relatively higher and prosogyr, followed by the stage of ribbed posterior and then wholly ribbed stage.

Observation and comparison:—A left internal mould, MM 3534, is 18.6 mm. long and 10.5 mm high. According to KITTL (1912) *D. pichleri* comprises specimens of various outlines. Among them a young specimen from Bosnia in fig. 5 on pl. 4 is the closest ally to this. The posterior extremity in the *pichleri*, however, is sharp and lies just below the hinge line, while in this it lies more ventrally and well-rounded; ribs are coarser and stouter in this than in *pichleri*.

Occurrence:—Rare at Zohoin in Sakawa.

14. *Daonella hiratai* KOBAYASHI and TOKUYAMA, new species

Plate 2, figure 14.

MM3535-2-14

Description:—Shell small, crescentic but dilating backward, 2–3 times as wide as high. Umbo prosogyrous, pointed at anterior fifth of long, straight hinge line. Ribs about 30, simple, round-topped covering antero-median to posterior surface, strongest in postero-median part, weakened anteriorly and effaced in anterior third. Concentric wrinkles distinct, closely spaced in anterior and umbonal region, becoming weaker and widely spaced in posterior. This shows posteriorly accelerated growth in the middle stage.

Observation:—An internal and external mould of open bivalved specimen (MM 3535) is 16 mm long, 6.5 mm high and depressed diagonally. Its original outline may be semi-oval or obliquely crescentic. Due to depression ribs are weakened on the anterior half. Therefore the true width of the anterior smooth area is indeterminable, although it is evident that the ribs are distinct in the posterior part but weakened forward.

Comparison:—In the umbonal position and the mode of ribbing it belongs undoubtedly to the KITTL's 6th group. In outline and ornaments it resembles *D. pichleri* MOJSISOVICS and *D. pauri* KITTL, both from Bukowina, Austria, but none has so wide anterior smooth area, anteriorly allocated umbo and so large width/height ratio and finer and more ribs. Finally, *D. sumatrensis* is the closest ally to this, but distinguishable from this by its smaller width/height ratio.

Occurrence:—One specimen each from Zohoin in Sakawa and Semidani in the western extremity of the Fujinohira-Decke in the Sakuradani region in Awa.

VI. A Supplementary Note on *Halobia* in Japan

KOBAYASHI and ICHIKAWA (1949) proposed a new name, *Halobia aotii*, for

H. multistriata KOBAYASHI and AOTI (1943), because the latter was found to be duplicated by *Halobia kwaluana* var. *multistriata* VOLZ, 1899. Simultaneously, they instituted a new species, *Halobia kashiwaiensis*, for a form from the *Oxytoma-Mytilus* sandstone at Kashiwai in Sakawa basin, Kochi Pref. Later ICHIKAWA (1954 b) reported the occurrences of *H. kawadai* and *H. obsoleta* at several localities in the Sakuradani-Kito area, Tokushima Pref. and *H. molukkana*, *H.* aff. *austriaca* and *Halobia* sp. at Iwai near Itsukaichi, Tokyo Pref. (1954 a). Subsequently, NAKAZAWA (1955) described from the Nabae formation in Kyoto and Fukui Prefectures, *Halobia kawadai*, *H. obsoleta*, *H.* cfr. *aotii* and *H.* cfr. *austriaca* beside 3 indeterminable forms of the genus. Recently TAMURA (1958) reported *H. kawadai* and *H. molukkana* from Matsukuma in the Kuma region in central Kyushu.

In Nagato *Halobia* occurs in three beds. The oldest is *Daonella* bed in the Atsu series whence the junior author (1959) described 2 new species, *Halobia atsuensis* and *H. subsedaka*. The second is the Hirabara formation of the Mine series which contains *kashiwaiensis* and *kawadai* in two horizons. The third is the Aisaka-Okibe bed or the *aotii* bed, in which *kawadai* was also collected recently. *Aotii* occurs further in the upper Nakatsuka formation (TOKUYAMA, 1959).

Thus, 5 leading species of *Halobia* are in ascending order, namely, *atsuensis*, *kashiwaiensis*, *kawadai*, *aotii* and *obsoleta*. This succession is applicable to the Kochigatani, Nabae and Nagato faunas, although they are not quite distinct as zone species. They are commonly found together in the Kuma and Sakuradani faunas. As a general tendency the more off-shore the sediment, the less the facies variability. Therefore the "*Halobia* beds" look explicit in the Mine and Nabae formations on the continental side, but become obscure in Sakuradani and Kuma areas on the Pacific side. The number of zones and their distinctiveness match with the Carnic palaeogeography of West Japan in the following manner:

(1) 3 *Halobia* zones in the Atsu, Mine and Asa areas and Nabae formations of the intra-orogenic zone.

(2) 2 *Halobia* zones in the Kachigatani series of the Sakawa basin in the inner side of the peri-orogenic zone.

(3) No distinct *Halobia* zone in the Kochigatani series in the Kuma and Sakuradani areas in the outer side of the peri-orogenic zone, although the genus is a common member of the Kochigatani fauna of the areas.

(4) *Halobia* occurs rarely in the Sambosan limestone in the extra-orogenic zone.

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THE HALOBIIDAE FROM THAILAND

By

T. KOBAYASHI aud A. TOKUYAMA

With Plate IV

In his reconnaissance Wallace LEE discovered fossils on the road side 8 km. south of Chiang Rai near the northern border of Thailand. They were submitted by him to the U.S. Geological Survey in 1923. T. W. STANTON distinguished in the collection, *Hoernesia* (?) spp., *Macrodon* (?) sp., *Myophoria radiata* LOCZY, *Myophoria* sp. ex. gr. *M. leavigata* and *Trigonodus* (?) sp. and suggested Middle Triassic for this fauna.

Later HEIM and HIRTSCHI (1939) found pelecypods in the green shale formation in the north of Lampang on the highway to Chiang Rai. The fossil was identified as typical *Daonella* by WANNER, indicating the Middle to Upper Triassic age for the formation, Still later *Halobia* was identified by IMLAY among the pelecypods from the same locality (BURAVAS, 1957).

Lately, Triassic fossils were found further at two spots of the Mae Moh tributary, 50 km. east of Lampang. According to PITAKPAIVAN (1955) there are three fossiliferous beds. The Mae Moh collections were sent to KUMMEL for identification. As the result the followings were determined and Anisic to Carnic was suggested for the age of the fauna.

1. Doi Chang shale and sandstone containing *Balatonites*, *Beyrichites*, *Paratrachyceras*, *Ptychites* and *Sturia*.
2. Hong Hoi shale and sandstone containing *Paratrachyceras*, *Joanites*, *Halobia*, *Lobites*, *Balatonites* and *Sturia*.

2-3. Doi Chang or Hong Hoi sandstone and shale yielding *Joanites*, *Ptychites* and *Cladiscites*.

3. Fossiliferous limestone of Doi Chang with *Spirigera*.

Last summer (1958) Mr. Saman BURAVAS, chief of the Geological Survey Division, Royal Department of Mines, Bangkok, Thailand has sent the senior another a small lot of Mesozoic fossils for determination. Beside two specimens from Lampang district there is one from a formation at Na Thawi, Songkhala near Thailand-Malayan border, which was formerly thought Triassic but lately of Carboniferous age. Here the specimen in question is determined as a member of the Triassic Halobiidae and most probably a Carnic species of *Daonella*. Precisely speaking, the Halobiidae from the three loclaities are as follows:

1. *Daonella sumatorensis* from Na Thawi (S 1017/1938). This species was first described from northern Sumatra. According to VOLZ it coexists with *Daonella cassiana* and 6 spcies of *Halobia* including *styriaca* and cfr. *charlyana*. He assigned this fossil horizon to the Raibl equivalent.

2. *Daonella* sp. ex gr. *D. pichleri* from about 60 km. on Lampang—Chiang Rai Highway (TF 4). It is not so well preserved to discuss in detail.

3. *Halobia* cfr. *comata* and *H.* cfr. *styriaca* from a locality (TF 167) east of Lampang. *H. comata* is one of the most abundant species in Timor and a lower Carnic index in the eastern part of the Tethyan province, occurring from the Himalaya, Yunnan and South China. *H. styriaca* is another leading member of the Timorian fauna with which this Thailand form

is most probably conspecific. They are, however, not quite identical with *H. styriaca* (s. str.) which is an index to the Carnic stage of the North Alps, Dinaric Alps, Greece and (?) Spiti.

Thus these four forms are all related to the Carnic species of the Alpine-Himalayan province and especially of the Southeastern Asiatic regions. None of them is, however, common or closely related to the Carnic species of Japan or East Siberia.

In the recent compilation of the geology of Thailand BROWN and others (1953) proposed "Khorat series" to include the Kamawkala limestone and all other Mesozoic formations with the thought that the age of the series is Triassic and Jurassic. The Khorat series on the Khorat plateau is, however, as pointed out by the senior author (1958), a continental formation containing Dicotyledonous plants which must be either Palaeogene or younger Cretaceous in age. Therefore the marine Triassic and Jurassic formations in the median and western zones of Thailand must be excluded from the Khorat series. It is a remarkable fact that the Khorat series so defined is horizontal or gently undulated, while the Jurassic and Triassic formations are strongly folded. Therefore the principal phase of crustal movement in this part of Southeastern Asia must be in the Cretaceous or late Jurassic period.

The Hong Hoi greenish grey shale containing the Carnic *Halobiae* are distributed at some places between Lampang and Chiang Rai, presumably on the east side of a tectonic boundary between the western and median tectonic zones of Thailand. In further northeast in High Laos HOFFET has shown that the boundary in question is a thrust of the Burma arc on the North Laos arc. It is further a remarkable fact that a similar Carnic shale occurs in the southern part of Peninsular Thailand which the senior author thinks to belong also to the median zone. Then the Carnic Hong Hoi shale as well as the Middle Triassic Doi Chang shale are two important members in the stratigraphy of Thailand.

None of the above Triassic fossils has as yet been described or illustrated. Though the material which the authors examined is small and imperfecet, the above statement is documented with its palaeontological description. Here the authors record their warmest thanks to Mr. Saman BURAVAS for the supply of the interesting material.

Genus *Daonella* MOJSISOVICS

Group of *D. pichleri*

1. *Daonella* (?) ex gr. *D. pichleri* MOJSISOVICS

Plate IV, figure 8

MM3561-4-8

A fragment of a right valve at hand is provided with stout, straight, simple, regular and round-topped ribs, widest in middle and narrowing backwards though still distinct. The ribs suggest the greater possibility of being a *Daonella* rather than a *Halobia*. If so, it may belong to KITTL's *pichleri* group, although its outline is unknown. Its ribs closely resemble those of *pauli* KITTL from the Ladinic of Bukowina, but the anterior flattened subhinge area is not so wide as *pauli*. If the area is absent, it may be related to *reticulata* or *pichleri*.

Occurrence:—Greenish grey shale in stream cutting near 60 km. on Lampang-Chiang Rai Highways, northwest Thailand (TF 4). According to BURAVAS this is in the same horizon with the Hon Hoi shale containing ammonites and *Halobia*. This specimen has been thought a *Halobia*.

2. *Daonella sumatrensis* VOLZ

Plete IV, figures 5-7.

1899. *D. sumatrensis* VOLZ, *Z. Deutsch. Geol. Ges., Bd. 51*, S. 30, Taf. 1, Fig. 2, 3.

Description:—Shell small, subovate, obliquely elongated and longer than high. Hinge straight, long, rounded at anterior end and obtusely angulated at posterior end. Umbo prosogyrous at about anterior 1/5. Ribs simple, fine, present only in postero-ventral part; *Posidonia*-like stage long; concentric wrinkles distinct through surface.

Observation and comparison:—A nearly complete specimen (MM 3559/1, fig. 1) is 7.3 mm. long and 4.1 mm. high; several fragmentary specimens similar in size, all somewhat compressed. The ribbing, outline and dimension assign this form to Carnic *sumatrensis* VOLZ, although ribs are somewhat finer, weaker and a little more than the typical form. Among Japanese species *hiratai* is the closest, but shorter and has a less prominent umbo.

Occurrence:—Several shells in a small slab of fine greenish grey clayslate from a tributary of Khlong Mak, Na Takwi, Songkhla near Malayan Border (S 1017/1938). VOLZ's is coexistent with 4 *Halobiae* and lies below the *styrica-cassiana* zone in north Sumatra.

Genus *Halobia* BROWN

Group of *H. styriaca*

4. *Halobia* cfr. *styriaca* by KRUMBECK, 1924.

Plate IV, figure 10.

1924. *Halobia styriaca*, KRUMBECK, *Pal. Timor, 22. Bd.*, S. 132, Taf. 187, Fig. 8; Taf. 188, Fig. 10

A photograph of *Halobia* sent from BURAVAS closely resembles *styriaca* from Timor. It is characterized by subrounded outline, short hinge, regular and later bifurcating ribs and flattened posterior subhinge area. In comparison with typical *styriaca* it is more rounded and has a shorter hinge and more ribs. RENZ's Greek form (1906) has a longer hinge and VOLZ's Sumatra form (1899) bears a smaller number of ribs. KRUMBECK's Timor form is closest, although ribs are more numerous and more regularly bifurcated in it. Together with Timor form, it can be separated from the typical Alpine species at least in subspecific rank.

Occurrence:—Greenish shale at railway cutting between Pong Pui and Phaukho, east of Lampang (TF 167). It is correlated to Hong Hoi shale.

Group of *H. comata*

3. *Halobia* cfr. *comata* BITTNER

Plate IV, figure 9.

1899. *Halobia facigera* BITTNER, *Pal. Indica, Ser. 15, Vol. 3*, p. 45, pl. 7, fig. 15.
1899. *H. comata* BITTNER, *ibid.*, p. 46, pl. 7, fig. 13.
1899. *H.* cfr. *comata* BITTNER, *ibid.*, p. 47, pl. 7, fig. 16.
1908. *H. comata*, DIENER, *ibid., Vol. 5*, p. 47, pl. 3, figs. 2-4.

1912. *H. fascigera*, KITTL, Halobiidae usw. S. 1571.
1912. *H.* cfr. *comata*, KITTL, *ibid.* S. 156.
1912. *H.* cfr. *comata*, MANSUY, *Mem. Serv. géol. de l'Indochine, Tom 1, No. 1, pt. 2.*. p. 130, pl. 24, fig. 6.

A laterally compressed right valve beside fragments is more or less diagonally elongated; umbo prosogyrous, at anterior 2/5 of hinge. Anterior ear wide, gently inflated and divided into two parts; dorsal part narrow and concave, while ventral is wide, inflated and defined by a distinct furrow. Ribs very fine, simple, narrow and not flexiate and weakened posteriorly. Concentric wrinkles distinct in young.

Due to compression postero-median ribs look finest; anterior ones widest; concentric wrinkles most distinct in antero-median part. A posterior subhinge area is fairly wide and provided with or without faint ribs, but whether it is secondary or not is a question.

Comparison:—This species was originally described from the Carnic of the Himalaya. According to KITTL his *comata* group is nearly equilateral, but Timor collection comprises various forms as KRUMBECK (1924) included oblique *fascigera* in it. Thailand specimens are more or less oblique and higher than others, although they are laterally compressed. The ribbing and ear safely assign them to *comata*. If their posterior area is original, they are related to *H.* cfr. *superbescens* by KRUMBECK from Timor, or MOJSISOVICS' original form from Hallstatt. KRUMBECK's is somewhat different in the shape of anterior ear.

Occurrence:—Same as the preceding (TF 167 by BURAVAS).

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T. KOBAYASHI and A. TOKUYAMA

Daonella in Japan

Plate I

Explanation of Plate I

Figs. 1, 2: *Daonella indica* BITTNER ..... p. 14
1: Left internal mould (MM 3495), ×1; 2: right internal mould (MM 3478) showing arcuate ribs, ×1; loc.: Zohoin.

Fig. 3: *Daonella* cfr. *spitiensis* BITTNER ..... p. 15
A right internal mould (MM 3496), ×1.5; loc.: Zohoin.

Figs. 4, 5: *Daonella alta* YABE and SHIMIZU ..... p. 13
4: Gypsum cast of a right external mould (MM 3476), ×1.5
5: a left internal mould with arcuate ribs (MM 3474), ×1; loc.: Zohoin.

Figs. 6, 7: *Daonella subquadrata* (s. s.) YABE and SHIMIZU ..... p. 19
6: Full grown specimens (MM 3516), ×1
7: a left internal mould (MM 3517), obliqu form, ×1; loc.: Zohoin.

Figs. 8–11: *Daonella subquadrata symmetrica* KOBAYASHI and TOKUYAMA ..... p. 19
8: Holotype (MM 3525), clay cast of a left external mould, ×1.5
9: gypsum cast of a right external mould (MM 3526), ×1.5
10: a right internal mould (MM 3527), ×1
11: a left internal mould (MM 3528), ×1.5; loc.: Zohoin.

Figs. 12,13: *Daonella subquadrata zohoinensis* KOBAYASHI and TOKUYAMA ..... p. 19
12: Holotype (MM 3510), a left internal mould, ×1;
13: a right internal mould (MM 3511), ×1; loc.: Zohoin.

13 MM 3511

3 MM 3496

1 MM 3495

8 MM 3525

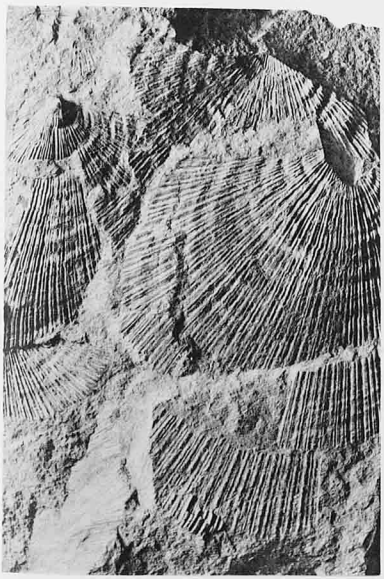
4 MM 3476

9 MM 3526

11 MM 3528

7 MM 3517

5 MM 3474



6

12

MM 3510

10

2

MM 3516

MM 3498

MM 3527

Explanation of Plate II

Figs. 1, 2: *Daonella indica* BITTNER ..... p. 14
Immature left valves; 1: (MM 3486), ×2; 2: (MM 3480), ×3; loc.: Zohoin.

Figs. 3–6: *Daonella kotoi* MOJSISOVICS ..... p. 16
3: Holotype, clay cast of the right external mould (MOISISOVICS' type of Taf. 2, Fig. 3), ×1.
4: a left internal mould (MM 3487) with narrow ribs, ×1.
5: a right internal mould (MM 3488) with wide ribs, ×1.
6: an immature left valve (MM 3489), ×2; loc.: Zohoin.

Fig. 7: *Daonella kotoi* MOJSISOVICS var. ..... p. 17
A variety (MM 3507) with trifurcate ribs, ×1.5; loc. Kuroiwadani near Ino.

Fig. 8: *Daonella sakawna* MOISISOVICS ..... p. 17
Holotype, modeling cast of the MOJSISOVICS' type specimen of Taf. 2, fig. 4 (MM 5002), ×2; loc.: Zohoin.

Figs. 9, 10: *Daonella subquadrata* YABE and SHIMIZU ..... p. 19
9: Immature forms of *subquadrata* (s. s.) and *zohoinensis*, MOJSISOVICS' type specimen of *sakawana* (MM 5003), (Taf. 2, Fig. 5), ×2; loc.: Zohoin.
10: an immature right internal mould of *subquadrata* (s. s.) (MM 3518), ×2; loc.: Koretomo near Ino.

Fig. 12: *Daonella pectinoides* KOBAYASHI and TOKUYAMA ..... p. 20
Holotype, (MM 3532), right internal mould, ×2; loc.: Zohoin.

Fig. 13: *Daonella asymmetrica* KOBAYASHI and TOKUYAMA ..... p. 22
Holotype, (MM 3534), left internal mould, ×2; loc.: Zohoin.

Fig. 14: *Daonella hiratai* KOBAYASHI and TOKUYAMA ..... p. 22
Holotype, (MM 3535), open internal mould, ×2; loc.: Zohoin.

Fig. 15: *Daonella iwayai* KOBAYASHI and TOKUYAMA ..... p. 15
A fragment of an external mould (MM 3498) showing furrows of 3 orders, ×1; loc.: Zohoin.

10 MM3518

2 MM3480

6 MM3489

1 M3486

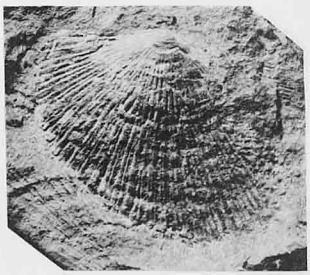
4 MM3487

12 MM3532

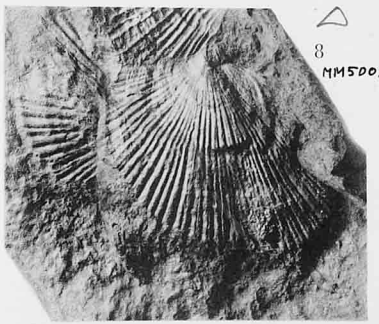
13 MM3536

14 MM3535

7 MM3507



11 MM3512



8 MM5002

5 MM3488

15 MM3498

9

MM3003

3

MM5001

Explanation of Plate III

Fig. 1: *Daonella kotoi* MOJSISOVICS ..... p. 16
A left internal mould (MM 3503), ×1; loc.: Tsuzuradani at Usugatani in the Sakuradani region; HASHIMOTO coll.

Fig. 2: *Daonella yoshimurari* KOBAYASHI ..... p. 12
A left valve (MM 3472), ×4; loc.: at a roadside between Shirogawara and Minami Omine.

Figs. 3, 4: *Daonella indica* BITTNER ..... p. 14
3: A right valve (MM 3538), ×1; loc.: Makio at Usugatani.
4: a deformed left internal mould (MM 3539), ×1; Naise at Junisha in the Sakuradani region; HASHIMOTO coll.

Fig. 5: *Daonella subquadrata zohoinensis* KOBAYASHI and TOKUYAMA ..... p. 19
Immature specimens (MM 3514) showing *Posidonia*-like stage, ×3; loc.: Koretomo.

Fig. 6: *Daonella pectinoides* KOBAYASHI and TOKUYAMA ..... p. 21
A left valve (MM 3533), ×5; loc. Koya-Mizo; HASHIMOTO coll.

Fig. 7: *Daonella multistriata* YABE and SHIMIZU ..... p. 20
Holotype, modelling cast of the YABE & SHIMIZU's type specimen of pl. 11, fig. 12, (MM5004), ×1; loc.: Rifu, Tohoku Univ. coll.

Figs. 8, 9: *Daonella iwayai* KOBAYASHI and TOKUYAMA ..... p. 15
8: Holotype (MM 3497), left internal mould, ×1: Tsuzuradani at Usugatani; HASHIMOTO coll.
9: A fragment of a full grown specimen (MM 3481), ×1; loc.: Kuroiwadani.

Fig. 10: *Daonella tenistriata* KOBAYASHI and TOKUYAMA ..... p. 13
Holotype (MM 3473), clay cast of an open specimen, ×1.5; loc.: Zohoin.

Figs. 11, 12: Sakuradani specimens showing the mode of deformation. ..... p. 14
11: *D. indica* (MM 3540), ×1; loc. Tsuzuradani, Usugatani; HASHIMOTO coll.
12: *D. indica* and *subquadrata* (MM 3531), ×2; loc. Junisha.

1 MM 3501

2 MM 3472

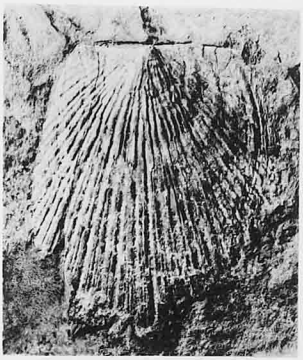
3 MM 3538

5 MM 3514

7 MM 3004

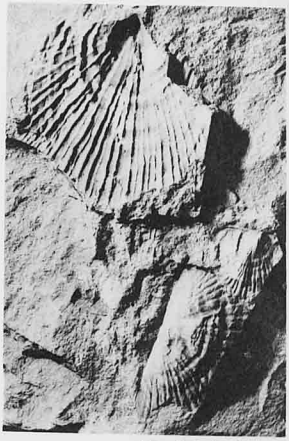
6 MM 3533

4 MM 3539



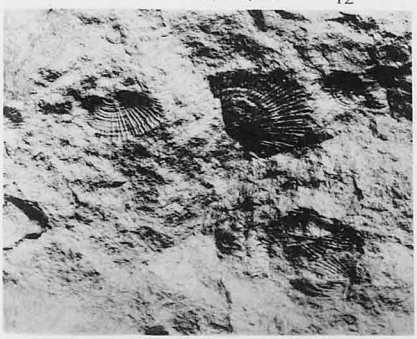
8 MM 3497

10 MM 3473



11 MM 3540

MM 3531 12



9 MM 3481

Explanation of Plate IV

Fig. 1: *Daonella indica* BITTNER ..... p. 14
A laterally compressed right valve (MM 3485), ×1; loc. Tsuzurazaka at Usugatani in Sakuradani region.

Figs. 2, 3: *Daonella kotoi* MOJSISOVICS ..... p. 16
Laterally compressed right valves (MM 3505, 3504), ×2; loc. ditto.

Fig. 4: *Daonella iwayai* KOBAYASHI and TOKUYAMA ..... p, 15
A right valve (MM 3537), showing the manner of defermation; ×1, loc. ditto.

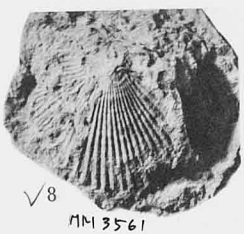
Figs. 5-7: *Daonella sumatrensis* VOLZ ..... p. 29
Clay casts of left valves (figs. 1 & 3) and a right valve (MM 3559/1-3), ×3; loc.: Tributary of Khlong Mak, Na Takwi, Songkhla near Malayan Border (S 1017/1938)

Fig. 8: *Daonella* (?) ex gr. *D. pichleri* MOJSISOVICS ..... p. 28
A clay cast of a right external mould (MM 3561), ×1.5. Loc.: At a stream cutting near Km. 60 on Lampang-Chiang Rai Highway, northwest Thailand. (TF 4).

Fig. 9: *Halobia* cfr. *comata* BITTNER ..... p. 29
A clay cast of a right external mould (MM 3560); ×1. loc.: At a railway cutting between Pong Pui and Phaukho, east of Lampang (TF 167).

Fig. 10: *Halobia* cfr. *styriaca* by KRUMBECK ..... p. 29
A photograph sent from BURAVAS; loc.: ditto.

All illustrated specimens except fig. 10 are kept in the Geological Institute, University of Tokyo.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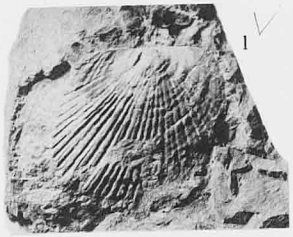
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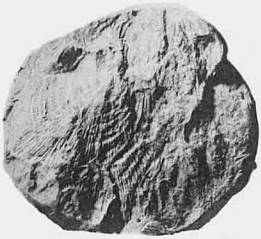
5 (1) MM 3559

6 (3)

MM 3559


9 MM 3560


2
MM 3504

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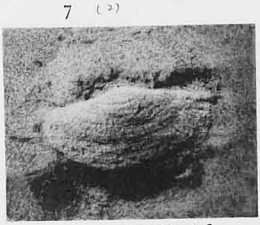
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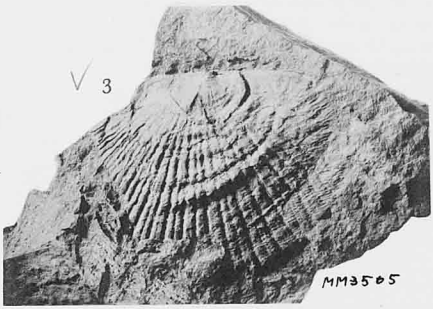
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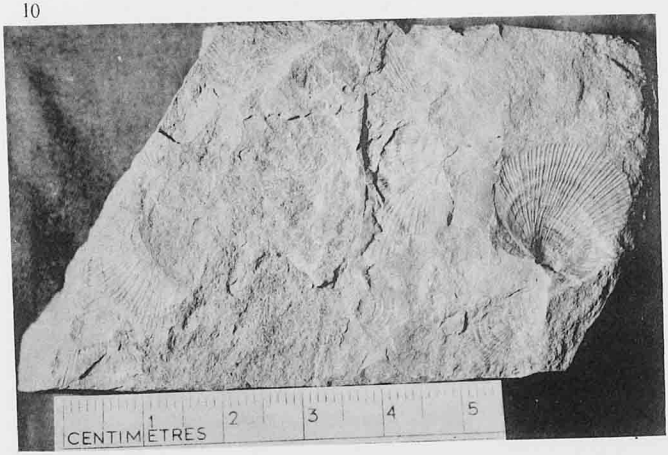

4 MM 3537