

Tertiary and Pleistocene Brachiopods of Okinawa Ryukyu Islands

GEOLOGICAL SURVEY PROFESSIONAL PAPER 314-A



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By G. ARTHUR COOPER

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 314-A



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 60 cents (paper cover)

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 4. *Jolonica*
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SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

TERTIARY AND PLEISTOCENE BRACHIOPODS OF OKINAWA, RYUKYU ISLANDS

By G. ARTHUR COOPER¹

ABSTRACT

This paper describes late Tertiary and early Pleistocene brachiopods from Okinawa in the Ryūkyū Chain. Thirteen genera are recognized and twenty species listed. Of these one genus and seven species are new. The described brachiopods have affinities mostly with fossil and Recent Japanese species but the range of some genera is extended southward from Japan while the range of a few is extended northward from the south Pacific to mingle with the Japanese elements.

INTRODUCTION

The brachiopods forming the subject of this report were collected by McClelland Dings, F. Stearns MacNeil, Delos E. Flint, Maxim M. Elias, Raymond A. Saplis, Warren Fuller, and Gilbert Corwin during a geological survey of Okinawa by the U. S. Geological Survey in 1946-48. The collection numbering about 500 specimens contains new and interesting species. In addition to the Geological Survey collection, the writer studied about 125 specimens from Katchin Hanto Peninsula, southern Okinawa, collected by Allan Graffam and belonging to the National Museum. These two collections add substantially to our knowledge of the brachiopods. The Geological Survey collection is deposited in the National Museum.

Before the present study little was known of the brachiopods of the Ryūkyū Islands and Okinawa. Hanzawa (1935) made a study of these islands and the southwest coast of Formosa over a period of several years ending in 1932. Brachiopods collected by him from the "Ryūkyū limestone" were described in 1935 by Yabe and Hatai. These authors recognized seven species, five of which are represented in the collections from Okinawa in the Geological Survey and the National Museum. Not all the species recorded by Yabe and Hatai are from Okinawa, some are from Kikai Island and Formosa. *Discinisca kamikatetuensis* Yabe

and Hatai, one of the seven species, was not seen in the collections from Okinawa. *Neohemithyris lucida* (Gould) another species from this island group mentioned by Yabe and Hatai proves to belong to the genus *Basiliola*. The other five species are: *Gryphus hanzawai* Y. and H., *Jolonica ryukyuensis* Y. and H., *Japanithyris* (here referred to *Campages*) *nipponensis* Yabe and Hatai, *Pictothyris picta* (Dillwyn) and *Kikaithyris hanzawai* (Yabe). Only the last two are reported from Okinawa by Yabe and Hatai.

The only other brachiopod from Okinawa beside those mentioned above is *Terebratulina japonica* (Sowerby) reported by Hatai (1940, p. 228) despite the fact that Yabe and Hatai (1935, p. 94) remark on the absence of *Terebratulina* from the Ryūkyūs. They also state that *Craniscus*, *Campages*, and *Laqueus* are lacking, but specimens of the last two genera are in the Geological Survey collection. Furthermore, Yabe and Hatai did not suspect that their *Japanithyris* was, in reality, a species of *Campages*.

The complete list of Okinawa brachiopods is arranged below by geological horizon:

Miocene (Yonabaru clay)

Jolonica macneili Cooper, n. sp.

Miocene or Pliocene (Shinzato tuff)

Gryphus stearnsi (Dall and Pilsbry)

Jolonica macneili Cooper, n. sp.

Laqueus elongatus Cooper, n. sp.

Terebratulina subcarinata Cooper, n. sp.

sp. indet.

Shinzato (?) tuff (or Chinen sand), horizon uncertain, locality 17480

Basiliola sp.

Dallina raphaelis (Dall)

Gryphus stearnsi (Dall and Pilsbry)

sp.

Laqueus quadratus Yabe and Hatai

Tegulorhynchia döderleini (Davidson)

Jolonica macneili Cooper, n. sp.

ryukyuensis Yabe and Hatai

Terebratulina indet.

¹ Smithsonian Institution, Washington, D. C. Published by permission of the Secretary of the Smithsonian Institution.

Pliocene (Nakoshi sand)

Campages nipponensis (Yabe and Hatai)*Kikaitheiris hanzawai* (Yabe)*Pictothyris picta* (Dillwyn)*Terebratulina subcarinata* Cooper, n. sp.

Pliocene (Naha limestone)

Campages nipponensis (Yabe and Hatai)**Discinisca kamikatuensis* Yabe and Hatai*Frenulina sanguinolenta* (Gmelin)*Gryphus hanzawai* Yabe and Hatai*stearnsi* (Dall and Pilsbry)*Jolonica elliptica* Cooper, n. sp.*ryukyuensis* Yabe and Hatai*Kikaitheiris hanzawai* (Yabe)*Laqueus elongatus* Cooper, n. sp.*quadratus* Yabe and Hatai

sp. 1

Basiliola nitida Cooper, n. sp.*Basiliola* sp.*Pictothyris picta* (Dillwyn)*Rhytirhynchia hataiana* Cooper, n. sp.*Terebratulina japonica* (Sowerby)*perplexa* Cooper, n. sp.*subcarinata* Cooper, n. sp.

sp. 1

sp. indet.

Pleistocene (Yontan limestone)

Frenulina sanguinolenta (Gmelin)*Kikaitheiris hanzawai* (Yabe)*Rhytirhynchia hataiana* Cooper, n. sp.*Terebratulina perplexa* Cooper, n. sp.*subcarinata* Cooper, n. sp.

sp. indet.

The above list increases the generic representation of a fauna having affinities with Japanese faunas fossil and Recent. Hitherto only one rhynchonellid was known from Okinawa. Now, four representing three genera are known. *Basiliola* is reported for the first time from this region. Heretofore the genus was known only from Hawaii, Borneo, the Celebes, and the Philippines. *Tegulorhynchia döderleini*, known today in Japanese waters and southward to Borneo, is here reported in the fossil state for the first time. *Rhytirhynchia hataiana* is a newcomer to the Japanese realm. Its closest affinities are with another species of the genus from the Indian Ocean.

Terebratulina is widespread and is known in Japanese waters as well as areas from Japan southward through the Philippines and on to Australia. The species from Okinawa are like living forms and present no unusual features.

Gryphus is another genus of wide distribution occurring in Japanese waters, the East Indies, and Australia. *Gryphus stearnsi* is reported for the first time as a fossil, but the specimens seem to be closely related to the living forms. *Gryphus hanzawai* is unusual for its small size and elongated form, but several species having this form are known from Tertiary beds in

New Zealand and Australia. A small specimen in the National Museum collection of Recent brachiopods not unlike that of *G. hanzawai* (pl. 3, fig. 32-39) was called *G. davidsoni* by Dall.

Frenulina is a common Recent brachiopod, being known from the Hawaiian Islands and Japan south around the Philippines to the Celebes, but is rare as a fossil.

Jolonica has hitherto been a poorly known genus. It lives in waters of the Philippines and the Malay Archipelago. A small species occurs in Japanese waters. Fossil species of the genus are not rare on Okinawa—one species occurs in the Miocene (Yonabaru clay) and two others are known from the higher Naha limestone. *Laqueus* is more closely related to Japanese forms as its range south is, so far as known, not extensive. *Dallina* is likewise common in Japanese waters but has also been identified in the Miocene of Fiji.

Pictothyris is a Japanese genus. *Kikaitheiris* is a closely related form but is not known to be living.

The specimens here referred to *Campages* were identified as *Japanithyris* by Yabe and Hatai. The relationship of these genera has been clouded by uncertainty concerning the interior details of the Japanese *Japanithyris mariae*. This is now known to be identical to *Campages basilanica* making *Japanithyris* a junior synonym of *Campages*. At any rate *Campages* is in Japanese seas as well as from the waters of the Philippines.

The affinities of the Okinawa brachiopods thus prove to be predominantly with Japanese species living and fossil, but connections with the Philippines are also clearly indicated.

SYNONYMY AND REFERENCES

Nearly all that is known about Japanese Tertiary and Recent brachiopods is summarized by Hatai (1940) in an exhaustive, well illustrated treatise. Therefore, it seems unnecessary in the present work to give detailed synonymies, and I have cited only the original description, an easily accessible publication, and the reference in Hatai 1940. Little has been done since 1940.

The same remarks hold for references—because Hatai (1940) gives many pages of bibliography. Only the major works referred to beside Hatai, and pertinent reports published after 1940, are cited here.

AGE OF THE BRACHIOPODS

The Yonabaru clay is the oldest Tertiary formation yielding brachiopods. Only one species, the oldest species of *Jolonica* known occurs in this formation.

The age of the Shinzato tuff is Miocene or Pliocene. This has yielded five brachiopods which include the

*Not found in the U. S. Geological Survey collections.

Jolonica from below and three species that also appear in younger formations.

Locality 17480 has not yet been properly dated. It is believed to belong either to the Shinzato tuff or to the Chinen sand. The brachiopod assemblage from this formation contains *Dallina* and *Tegulorhynchia*, genera not seen in any of the other formations.

The Chinen sand is the lowest deposit of the Pliocene but has yielded only three brachiopods, one with connections to the Miocene but the other two appearing in higher rocks.

The Pliocene (Naha limestone) has yielded the largest number of brachiopods, 17 named species. Some of these species are restricted to this formation but there are a few survivors from the Chinen sand.

The Yontan limestone, highest and youngest of the formations contains 5 named species all of which are present in the underlying Naha limestone.

Hatai (1939, p. 476) referred the Okinawa brachiopods described by him and Yabe to the early Pleistocene. According to him the upper Pleistocene deposits contain only species of brachiopods that are living today.

The foregoing ages of these sediments are based on fossils other than brachiopods, which at present are too little known to be diagnostic guide fossils.

LOCALITIES

The numbers given below are those assigned to the various localities on Okinawa. The initials and numbers following the locality designation refer to the collector and his field number, as follows: DF=Delos E. Flint, FSM=F. Stearns MacNeil, ME=Maxim K. Elias, RS=Raymond A. Saplis, and WF=Warren Fuller.

17445 (RS 75) Yonabaru clay, fossiliferous bed at base of low hill on south side of Highway 40 about 1.0 mile west of the junction of Highways 13 and 137 in Yonabaru.

Jolonica macneili Cooper, n. sp.

17452 (RS 319) Shinzato tuff, fossiliferous beds above pumice quarry overlooking Okinawa Central Prison, about 0.4 mile east-southeast of Shinzato.

Brachiopod indet.

17453 (RS 346, RS 364) Shinzato tuff, low road cut at end of small spur of hill west of road, about 0.6 mile north of junction of road with Highway 64 at Asato.

?*Jolonica macneili* Cooper, n. sp.

17457 (RS 361) Shimajiri marl, road cut at base of low hill near bend in Highway 64, 0.5 mile northeast of Minatoga.

Brachiopod indet.

17458 (RS 351) Shinzato tuff, blue gray silty sand exposed at base of seaciff that forms a headland about 0.8 mile south of Gushichan.

Gryphus stearnsi (Dall and Pilsbry)

Laqueus elongatus Cooper, n. sp.

Terebratulina subcarinata Cooper, n. sp.

17460 (RS 348) Naha limestone, cliff at top of south bank of small reentrant into which a small stream falls, about 0.1 mile southeast of bend in Highway 64 near east edge of Gushichan.

Jolonica elliptica Cooper, n. sp.

Terebratulina sp. 1

17461 (RS 349) Naha limestone, cliff at top of steep slope on south bank of stream, 0.25 mile southeast of Gushichan.

Terebratulina japonica (Sowerby)

17462 (RS 350) Naha limestone, lower part of limestone forming main part of seaciff at same locality as 17458.

Campages nipponensis (Yabe and Hatai)

Jolonica elliptica Cooper, n. sp.

Laqueus elongatus Cooper, n. sp.

Pictothyris picta (Dillwyn)

17463 (RS 352) Naha limestone, high limestone seaciff forming a small reentrant about one mile northeast of Mabuni.

Campages nipponensis (Yabe and Hatai)

Jolonica elliptica Cooper, n. sp.

Laqueus elongatus Cooper, n. sp.

quadratus Yabe and Hatai

17464 (RS 388) Naha limestone, large quarry facing East China Sea just south of Sakibaru-saki.

Kikathyris hanzawai (Yabe)

17466 (RS 390) Naha limestone, large limestone quarry on top of cliff overlooking Naha Bay, 0.3 mile north of the intersection of Highways 1 and 40.

Kikathyris hanzawai (Yabe)

17473 (RS 383) Naha limestone, quarry on west side of Highway 7 about 0.2 mile south of the intersection of Highways 7, 13, and 52, about 1 mile east of Itoman.

Campages nipponensis (Yabe and Hatai)

Jolonica ryukyuensis (Yabe and Hatai)

17475 (RS 368) Naha limestone, roadcut of secondary road crossing limestone cliff about one mile east-southeast of Kiyan.

Gryphus stearnsi (Dall and Pilsbry)

17480 (FSM 27) Shinzato? tuff, high road cut along Highway 64 about 0.1 mile west of sharp bend in road about 0.3 mile east of Yashitomi. This may be Chinen sand.

Bastiola sp.

Dallina raphaelis (Dall)

Gryphus stearnsi (Dall and Pilsbry)

sp.

Laqueus quadratus Yabe and Hatai

Tegulorhynchia döderleini (Davidson)

17482 (FSM 28) Chinen sand (a, base; b, middle part; c, upper beds just below limestone), section in both abandoned road cut and new road cut at Chinen-misaki.

Jolonica ryukyuensis (Yabe and Hatai)

macneili Cooper, n. sp.

Laqueus elongatus Cooper, n. sp.

Terebratulina japonica (Sowerby)

17484 (FSM 14) Naha limestone, road cut on south side of Highway 60 about 0.6 mile west of the junction with Highway 3.

Gryphus hanzawai (Yabe and Hatai)

Kikathyris hanzawai (Yabe)

Pictothyris picta (Dillwyn)

17486 (DF 112) Nakoshi sand, from beach cliff on Unten Ko, 0.25 mile north of Shima Unten.

Kikathyris hanzawai (Yabe)

- 17487 (DF 130) Naha limestone, small steep sided hill on southern outskirts of Nakasoni.
Gryphus hanzawai (Yabe and Hatai)
- 17488 (FSM 7) Naha limestone, hard limestone underlying gravel, about 0.2 mile, downhill from quarry near top of winding hill on Highway 24, 0.3 mile west of site of Momobaru.
Kikaithyris hanzawai (Yabe)
Terebratulina perplexa Cooper, n. sp.
subcarinata Cooper, n. sp.
- 17497 (FSM 29) Naha limestone (a: lower bed, b: upper bed), edge of Chinen plateau overlooking Baten-ko above the village of Sashiki.
Brachiopod indet.
Jolonica ryukyuensis Yabe and Hatai
Pictothyris picta (Dillwyn)
Terebratulina subcarinata Cooper, n. sp.
- 17498 (FSM 36, 22-251-2) Naha limestone, lower part of large quarry south of docks at Naha Harbor, about 0.2 mile south of the junction of Highways 3 and 7.
Kikaithyris hanzawai (Yabe)
Pictothyris picta (Dillwyn)
- 17499 (WF 135) Naha limestone, quarry about 0.1 mile east of the southeast corner of Kiyuna.
Terebratulina subcarinata Cooper, n. sp.
- 17504 (WF 17) Naha limestone, quarry on east side of Highway 5 near foot of long hill, about 0.3 mile north of intersection of Highways 5 and 130.
Gryphus hanzawai Yabe and Hatai
Rhytirhynchia hataiana Cooper, n. sp.
- 17505 (WF 20) Naha limestone, same as 17504.
Laqueus sp. 1
Pictothyris picta (Dillwyn)
- 17516 (WF 28) Naha limestone, quarry on north side of Highway 30, about 0.3 mile northeast of junction of Highways 1 and 30.
Rhytirhynchia hataiana Cooper, n. sp.
- 17517 (WF 29) Naha limestone, quarry on south side of Highway 30, about 0.7 mile northeast of the junction of Highways 1 and 30.
Jolonica ryukyuensis Yabe and Hatai
Kikaithyris hanzawai (Yabe)
Terebratulina subcarinata Cooper, n. sp.
- 17518 (WF 32, WF 146, WF 154) Naha limestone, quarry about 0.3 mile west of Highway 5 and about 1.0 mile east of the junction of Highways 1 and 30.
Jolonica ryukyuensis Yabe and Hatai
Terebratulina perplexa Cooper, n. sp.
- 17519 (WF 47) Naha limestone, low cliff at end of small ridge extending out into rice paddies, about 0.75 mile northeast of the 37th Division General Hospital on Highway 1.
Gryphus hanzawai Yabe and Hatai
Jolonica ryukyuensis Yabe and Hatai
Rhytirhynchia hataiana Cooper, n. sp.
Terebratulina perplexa Cooper, n. sp.
subcarinata Cooper, n. sp.
- 17521 (WF 76) Naha limestone, quarry on east side of Highway 5 near foot of long hill, about 0.3 mile north of intersection of Highways 5 and 130.
Basiliola nitida Cooper, n. sp.
Pictothyris picta (Dillwyn)
Rhytirhynchia hataiana Cooper, n. sp.
Terebratulina sp. indet.
- 17522 (WF 145=WF 135?) Naha limestone, same as 17499.
Pictothyris picta (Dillwyn)
- 17524 (WF 155) Naha limestone, quarry south of sharp bend in Highway 5, about 0.7 mile southeast of the junction of Highways 5 and 34.
Pictothyris picta (Dillwyn)
- 17529 (WF 189) Naha limestone, road cut on west side of ravine about 0.75 mile southeast of the intersection of Highways 5 and 16.
Pictothyris picta (Dillwyn)
- 17534 (WF 237) Naha limestone, sea cliff at north end of small beach about 0.8 mile due west of road fork at west edge of Hanza.
Terebratulina subcarinata Cooper
- 17543 (WF 234) Yontan limestone, large quarry 200 yards east of Highway 6, about 0.7 mile southwest of the junction Highways 6 and 12 north of Hanza.
Terebratulina sp. indet.
- 17544 (WF 235) Yontan limestone, large quarry on hillside east of Highway 6, about 0.6 mile north of Sobe.
Frenulina sanguinolenta (Gmelin)
- 17547 (WF 240) Yontan limestone, quarry about 0.3 mile from western shore and about 0.9 mile west-southwest of the northern junction of Highways 6 and 12.
Brachiopod indet.
- 17560 (RS 367) Naha limestone, hillside outcrop near trail at base of low limestone cliff at top of steep slope overlooking Yonabaru-wan, about 0.75 mile east of Shinzato.
Terebratulina subcarinata Cooper, n. sp.
- 17572 (DF 145) Naha limestone, from excavation for tombs on the beach one mile north of Shoshi, Nakijin-Mura.
Gryphus hanzawai Yabe and Hatai.
Jolonica ryukyuensis Yabe and Hatai.
Kikaithyris hanzawai (Yabe)
Rhytirhynchia hataiana Cooper, n. sp.
Terebratulina sp. 1
sp. indet.
- 17575 (DF 155) Naha limestone, road cut at Imadomari, intersection of two roads on eastern edge of town, about 0.3 mile north of Highway 124.
?Terebratulina subcarinata Cooper, n. sp.
- 17577 (DF 157) Naha limestone, small quarry on west side of highway, 0.25 mile north of Kitazato, Kami-Motobu-Mura.
Pictothyris picta (Dillwyn)
- 17580 (DF 161) Naha limestone, coarse conglomerate bed 1 foot thick located about 15 feet below top of quarry on west side of Highway 124 about 0.3 mile north of Kitazato, Kami-Motobu-Mura.
Terebratulina sp. indet.
- 17582 (DF 163) Naha limestone, large quarry on east side of Highway 124 about 0.2 mile south of road junction west of Kushichin.
Jolonica sp. aff. *J. elliptica* Cooper, n. sp.
Terebratulina subcarinata Cooper, n. sp.
- 17583 (DF 164) Naha limestone, road cut and quarry west of Highway 124 about 150 yards south of road fork west of Kushichin.
Jolonica ryukyuensis Yabe and Hatai.
Pictothyris picta (Dillwyn)
Terebratulina subcarinata Cooper, n. sp.
sp. indet.

- 17586 (DF 167) Yontan limestone, large quarry on edge of plateau north of road along north shore of Urasaki-wan, about 0.8 mile west of Urasaki.
Terebratulina subcarinata Cooper, n. sp.
sp. indet.
- 17591 (DF 177) Yontan limestone, small cut 100 yards west of Highway 124 at southern edge of Kitazato (?Jahana), Kami-Motobu-Mura.
Brachiopod indet.
Kikaithyris hanzawai (Yabe)
Terebratulina subcarinata Cooper, n. sp.
- 17592 (DF 179) Naha limestone, from long cut just west of big bend in road from Urasaki to Jahana school, Kami-Motobu-Mura.
Kikaithyris hanzawai (Yabe)
- 17593 (DF 180) Yontan limestone, from quarry on the hill about 0.3 mile southeast of Urasaki.
Terebratulina subcarinata Cooper, n. sp.
- 17599 (DF 115) Nakoshi sand, old sea cliff at Kunjabaru, Nakifin-Mura, from cliff face where cliff and road meet near eastern part of settlement.
Campages nipponensis (Yabe and Hatai)
- 17600 (DF 116) Nakoshi sand, halfway up sea cliff above trail about 0.3 mile west of Kunjabaru.
Pictothyris picta (Dillwyn)
- 17601 (DF 117) Nakoshi sand, from road cut on road from beach to upper terrace level at the west end of Kunjabaru.
Kikaithyris hanzawai (Yabe)
Terebratulina subcarinata Cooper, n. sp.
- 17604 (DF 124) Naha limestone, from excavation for an outdoor theater, 0.2 mile north of Goechi (Koechi), Nakijin-Mura.
Kikaithyris hanzawai (Yabe)
- 17605 (DF 125) Naha limestone, small quarry halfway between Goechi (Koechi) and Jahana.
Kikaithyris hanzawai (Yabe)
- 17606 (DF 142) Naha limestone, quarry near coast 1.25 miles due north of Yonamine.
Frenulina sanguinolenta (Gmelin)
Terebratulina subcarinata Cooper, n. sp.
- 17607 (DF 143) Naha limestone, in road cut on secondary road to beach, 0.5 mile north-northeast of Sakiyama, almost on the beach.
Kikaithyris hanzawai (Yabe)
- 17609 (ME 2) Naha limestone (18 feet above the base), point 3 on road map by Maxim M. Elias.
Gryphus hanzawai Yabe and Hatai.
Kikaithyris hanzawai (Yabe)
- 17611 (FSM 15) Naha limestone (indurated gray limestone overlying white crumbly limestone), quarry in pinnacle in bend in Highway 16, 0.6 mile west of Chibana.
Terebratulina sp. indet.
- 17614 (FS 56) Naha limestone, small quarry west of Highway 12, 0.2 mile north of junction of Highways 12 and 6, near site of village of Uza, Bolo Point Peninsula.
Brachiopod indet.
- 17618 (FSM 54) Naha limestone, quarry on road leading up to top of south levee of Bisha-Cawa, at mouth of river, about halfway up hill.
Jolonica ryukyuensis Yabe and Hatai
Kikaithyris hanzawai (Yabe)
Terebratulina perplexa Cooper, n. sp.
- 17622 (FSM 1) Naha limestone (lower beds), quarry in west quadrant of the intersection of Highways 13 and 24, about 0.5 mile east of Koza.
Pictothyris picta (Dillwyn)
- 17623 (FSM 2) Naha limestone, small quarry on north side of creek just west of Highway 13, about 0.25 mile south of Chibana.
Kikaithyris hanzawai (Yabe)
- 17624 (FSM 3) Naha limestone, large quarry northeast of Highway 10, about 0.5 mile west of Gushikawa.
Campages nipponensis (Yabe and Hatai)
Jolonica ryukyuensis Yabe and Hatai
Terebratulina perplexa Cooper, n. sp.
subcarinata Cooper, n. sp.
- 17625 (FSM 4) Naha limestone, large quarry on south side of Highway 10, across road from village of Heanna, Peninsula of Katchin Hanto.
Pictothyris picta (Dillwyn)
- 17628 (FSM 8) Naha limestone (Basal limestone bed), about 0.3 mile down hill from quarry near top of winding hill on Highway 24, about 0.3 mile west of site of Momobaru.
Brachiopod indet.
Jolonica ryukyuensis Yabe and Hatai
Pictothyris picta (Dillwyn)
- 17630 (FSM 10) Naha limestone, cut on Highway 1 through natural levee along north bank of the Chatan Gawa.
Kikaithyris hanzawai (Yabe)
Terebratulina perplexa Cooper, n. sp.
subcarinata Cooper, n. sp.
- 17631 (FSM 26) Naha limestone (indurated marly facies), quarry on south side of Highway 24, about 0.5 mile west of junction of Highways 24 and 5.
Pictothyris picta (Dillwyn)
- 17633 (FSM 11, 22-333-14) Shinzato tuff, low cliff at canyon head just east of trail pass through ridge about 0.4 mile southwest of China.
Jolonica macneili Cooper, n. sp.
- 17635 (FSM 30) Naha limestone, quarry 0.2 mile east of village of Aragusuku.
Terebratulina sp. 1
- 17641 (FSM 52) Naha limestone, deep quarry west of Highway 6, about 1.1 miles south of road fork at west edge of Hanza. a, lowest; b, middle; c, highest.
Campages nipponensis (Yabe and Hatai)
- 17644 (FSM 55b) Yontan limestone, large quarry on hillside east of Highway 6 about 0.6 mile north of Sobe.
Terebratulina subcarinata Cooper, n. sp.
- 17646 (FSM 60) Yontan limestone, large quarry on hillside west of Highway 13 about 0.4 mile south of the junction of Highways 13 and 164 at Ishicha (Ishikawa).
Frenulina sanguinolenta (Gmelin)
? *Terebratulina subcarinata* Cooper, n. sp.

- 17649 (FSM 86) Naha limestone, large quarry south of creek and east of Highway 30, just north of Futema.
Picthothyris picta (Dillwyn)
Terebratulina sp. indet.
- 17656 (FSM 88U) Yontan limestone, large quarry west of Highway 1, just south of Kakazu Ridge and about 0.6 mile west of the junction of Highways 1 and 153.
Kikaithyris hanzawai (Yabe)
Terebratulina perplexa Cooper, n. sp.
- 17657 (FSM 67) Naha limestone, base of quarry west of Highway 1, about 0.3 mile north of Highway 20.
Kikaithyris hanzawai (Yabe)
- 17658 (FSM 68) Yontan limestone, quarry west side of Highway 1, about 0.25 mile north of the intersection of Highways 1 and 20.
Kikaithyris hanzawai (Yabe)
Rhytirhynchia hataiana Cooper, n. sp.
- 17660 (FSM 70) Yontan limestone, quarry between shore road and large limestone pinnacle, about 0.4 mile north-northwest of the intersection of Highways 1 and 20.
Kikaithyris hanzawai (Yabe)
- 17661 (FSM 71) Naha limestone, cut on small loop road west of shore road and south of small creek about 1.4 miles south of the mouth of Hiza-gawa (Bisha-gawa).
Jolonica ryukyuensis Yabe and Hatai
Kikaithyris hanzawai (Yabe)
- 17669 (FSM 79) Naha limestone, bulldozer trench on south side of secondary road about 0.8 mile southwest of the road circle at Kadena.
Gryphus hanzawai Yabe and Haitai
Jolonica ryukyuensis Yabe and Hatai
Kikaithyris hanzawai (Yabe)
Rhytirhynchia hataiana Cooper, n. sp.
Terebratulina perplexa Cooper, n. sp.
- 17670 (FSM 80) Naha limestone, roadcut through north levee of Hiza-gawa (Bisha-gawa) at mouth of river.
Jolonica ryukyuensis Yabe and Hatai
- 17671 (FSM 81) Naha limestone, west end of quarry north of road at top of steep hill about 0.8 mile due east of Kina.
Terebratulina subcarinata Cooper, n. sp.
- 17686 (FSM 354) Yontan limestone, quarry on north slope of Yuza-dake, about 1.2 miles west of Tomari and about 2.5 miles east of Itoman.
Frenulina sanguinolenta (Gmelin)
Terebratulina subcarinata Cooper, n. sp.
- 17729 (RS 347) Chinen sand, low cliff about 200 yards north of junction of Highways 9 and 64 near Gushichan.
Gryphus stearnsi (Dall and Pilsbry)
- USNM (Cooper)
 901 Naha limestone, 137th Navy Construction Brigade (Sea Bee Camp) quarry, Katchin Hanto.
Campages nipponensis (Yabe and Hatai)
Gryphus hanzawai Yabe and Hatai
Jolonica ryukyuensis Yabe and Hatai
Kikaithyris hanzawai (Yabe)
Picthothyris picta (Dillwyn)
Rhytirhynchia hataiana Cooper, n. sp.
Terebratulina perplexa Cooper, n. sp.
subcarinata Cooper, n. sp.

SYSTEMATIC DESCRIPTIONS

Superfamily RHYNCHONELLACEA Schuchert, 1896

Family RHYNCHONELLIDAE Gray, 1848

Tegulorhynchia döderleini (Davidson)

Plate 1, figures 34-51

Rhynchonella döderleini Davidson. Trans. Linnean Soc., ser. 2, v. 4, pt. 2, p. 172, pl. 25, figs. 14, 15, 1887.

Rhynchonella döderleini Davidson. Leidhold, Neues Jahrb. Mineral. Geol. Paläont., Band 45, p. 425-470, 1922.

Tegulorhynchia döderleini (Davidson). Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 214, pl. 8, figs. 56, 68, 70, 71, 1940.

Shell of about medium size for the genus, transversely pentagonal in outline; greatest width at middle; sides narrowly rounded; anterior margin truncated; valves of unequal depth, the brachial valve having the greater depth; anterior commissure strongly uniplicate; surface lamellose and costellate, a spine being produced anteriorly from each costella on each overlapping lamella.

Pedicle valve unevenly convex in lateral profile, the posterior half being gently convex but the anterior half flattened; anterior profile nearly flat to gently convex; beak nearly straight, pointed; foramen elongate-oval, hypothryd; deltidial plates thickened, conjunct in the adult; umbonal and posterior regions somewhat inflated; sulcus originating in anterior half or third, appearing abruptly, deep and wide, extending anteriorly as a broadly rounded but short tongue; flanks flattened and with gentle slopes.

Brachial valve moderately convex in lateral profile, the anterior half or two-thirds convex but the posterior flattened; anterior profile broadly and roundly domed; umbonal region flattened; median region swollen, the swelling continued to the anterior margin as a short low rounded fold, not strongly demarcated from the flanks; umbonal slopes gentle; flanks gently swollen and with steep lateral slopes.

Interior.—Pedicle valve with small thick teeth buttressed by strong dental plates; flabellate diductor scars enclosing the adductor impressions. Brachial valve without a cardinal process, the diductor muscles being attached in a transverse pit; socket ridges thick and stout united with concave plates to form deep, corrugated sockets; crural bases attached to sides of socket ridges without hingeplates intervening; crura short and stout.

Measurements, in millimeters

| Specimen | Measurements, in millimeters | | | |
|--------------|------------------------------|-----------------|----------|-----------|
| | Length | Brachial length | Midwidth | Thickness |
| 549317a----- | 13.6 | 11.6 | 16.9 | 8.5? |
| 549317b----- | 12.9 | 11.2 | 14.2 | 6.5 |
| 549317c----- | ? | 14.6 | 18.0 | ? |
| 549317e----- | 13.8 | ? | 17.5 | ? |

Types.—Figured hypotypes USNM 549317a-d and f, unfigured hypotype USNM 549317e. Hypotype 549317a shortened by crushing.

Horizon and locality.—Shinzato tuff ? or Chinen sand, USGS 17480.

Discussion.—This species is of considerable interest because it is the only known living spiny rhynchonellid and this is the first report of it as a fossil. The figured specimens and a few others in the collection are exceptionally well preserved and make it possible to illustrate features of the interior hitherto little known.

In the living state this species occurs in the China Sea and off Borneo as well as in the waters off Japan where it was originally found. Its known depth range is from 160 down to 340 fathoms. The specimens (USNM 299761) from Borneo are larger than the fossil forms here described.

Other living species of *Tegulorhynchia* are confined to Australian and Antarctic waters, at any rate to the extreme southern part of the Southern Hemisphere. This is true also of the fossil forms, which occur in the Tertiary of Australia, Tasmania, and New Zealand. One species from Patagonia hitherto classified as *Tegulorhynchia* is now referred to another genus. A Belgian species assigned here is doubtfully placed.

Compared with Recent specimens of *T. döderleini* the Okinawa examples are smaller and seem to be somewhat more finely ornamented. The specimens may, however, not be fully grown. Counts of the costellae at one, five, and 10 millimeters anterior to the beak of a large specimen (USNM 299761) are similar to counts made at the same intervals on one of the Okinawa specimens (USNM 549317a).

Basiliola nitida Cooper, n. sp.

Plate 1, figures 17-23

Neohemithyris lucida Yabe and Hatai (not Gould). Japanese Jour. Geology, Geography, Trans. and Abs., v. 12, nos. 3, 4, p. 94, pl. 14, figs. 13, 14, 1935; Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 210, pl. 1, fig. 44; pl. 6, figs. 106, 107, 1940.

Small for the genus, longer than wide; subpentagonal in outline with the maximum width slightly anterior to the middle; brachial valve deeper than the pedicle valve; posterolateral margins slightly concave and forming an apical angle of 85°; sides broadly rounded; anterior margin truncated; anterior commissure strongly uniplicate; surface smooth.

Pedicle valve having an even and gently convex lateral profile; anterior profile broadly and gently convex; beak moderately long, nearly straight; foramen small, elongate-oval, submesothyrid; deltidial plates conjunct but with slightly inflected posterior margin; umbonal and median regions gently swollen; sulcus poorly defined, originating in the anterior third; tongue

moderately long and broadly truncated anteriorly; flanks gently swollen.

Brachial valve with lateral profile evenly and moderately convex, much more convex than that of the pedicle valve; anterior profile broadly domed and with short precipitous sides; entire valve swollen and with the sides extended to meet the tongue of the pedicle valve.

Interior.—Unknown.

Measurements, in millimeters

| Specimen | Length | Brachial length | Maximum width | Thickness |
|-------------|--------|-----------------|---------------|-----------|
| 549314----- | 10.0 | 8.9 | 8.8 | 7.0 |

Types—Holotype USNM 549314.

Horizon and locality.—Naha limestone, USGS 17521.

Discussion.—This species is characterized by its small size, subpentagonal to oval outline, smooth surface, short beak and broad, truncated tongue on the pedicle valve. This may be the same species as Yabe and Hatai (1935) referred to *Neohemithyris lucida* (Gould). The specimen on which the foregoing description is based is an adult as shown by the thick shell and anterior concentration of growth lines. Consequently it cannot be referred to Gould's species which is larger and has a somewhat narrowly rounded tongue.

Neohemithyris is now placed in the synonymy of *Basiliola*, an older name. This is necessary because *Neohemithyris* has the beak characters and interior features of *Basiliola*.

Basiliola sp.

Plate 1, figures 24-33

Shell of about medium size for the genus; length and width nearly equal; outline subpentagonal; sides broadly rounded; anterior margin truncated; anterior commissure strongly uniplicate. Surface smooth.

Pedicle valve nearly flat in lateral profile but with the umbonal region slightly swollen; anterior profile nearly flat; beak short, obliquely truncated, nearly straight; foramen small circular, submesothyrid; deltidial plates conjunct, with elevated lip around anterior side of foramen; umbonal region gently inflated; sulcus originating at about the middle, broad and shallow; tongue moderately long, strongly rounded; flanks bounding sulcus slightly convex; umbonal slopes steep.

Brachial valve moderately convex in lateral profile, with the greatest curvature at the umbo; anterior profile strongly domed; umbo and median regions swollen, with precipitous lateral slopes, the entire front constituting a broad fold.

Interior.—Pedicle valve with pedicle collar thin and entire; teeth small, dental plates thin forming narrow chambers between lamellae and valve wall; muscle field short; vascula media visible, subparallel branching

near midvalve. Brachial valve with inner socket ridges thin, elevated and curved; outer hinge plates wide and flat; crura short, slightly curved, slightly divergent, concave inward.

Measurements, in millimeters

| Specimen | Length | Brachial length | Midwidth | Thickness |
|--------------|--------|-----------------|----------|-----------|
| 549315d----- | 13.0 | ? | 12.9 | ? |
| 549315a----- | 12.8 | 11.4 | 10.8+ | 9.3+ |

Types.—Figured specimens USNM 549315a, b, d, e; unfigured specimen used in preparing the description USNM 549315c.

Horizon and locality.—Shinzato tuff?, USGS 17480.

Discussion.—The brachiopods here referred to *Basiliola* are not given a specific name because they are badly deformed. They show all of the characters of *Basiliola*. The best preserved specimen (USNM 549315a) compared to recent specimens of *B. lucida* is quite similar and has the same long, rounded tongue. This specimen, however, is a small one. Others in the same lot indicate a larger and broader species than *B. lucida*. The Okinawa form is probably a new species.

This is the first report of *Basiliola* in the fossil state and the first report of it in a brachiopod assemblage made up of chiefly Japanese forms.

Rhytirhynchia Cooper, n. gen.

Usually small, subcircular to subpentagonal in outline; valves unequal in depth, the brachial valve having the greater depth; anterior commissure sulcificate; surface smooth.

Pedicle valve with circular to oval foramen, submesothyrid to mesothyrid; deltidial plates conjunct, and with posterior lip reflected; deltidial plates vestigial to obsolete; teeth large, stout, elongated, corrugated; muscle area small confined; vascula media extending almost to front margin and sending off three branches laterally. Genital area small.

Brachial valve with stout cardinalia; cardinal process lacking; socket ridges curving, thin; sockets excavated in shell tissue, not formed of separate plates, corrugated. Outer hinge plates small, gently concave, united with socket ridges and stout crural base; crura moderately long, stout, gently curved, crescentic in cross section and with the concave surfaces facing inward; muscle area small, rounded and with the individual scars not separated; genital areas small; vascula media extending anterolaterally and branching, one branch extending laterally and the other anteriorly, each secondary branch dividing again.

Type species.—*Hemithyris sladeni* Dall, Trans. Linnean Soc. London, ser. 2, Zoology, v. 13, pt. 3, p. 440, pl. 26, figs. 7–12, 1910. Dall's cotype USNM 111086 is here chosen as lectotype for the species.

Discussion.—The type species of this new genus has hitherto been placed in *Hemithyris* where it obviously does not belong because it is smooth, differently folded, has a lesser development of the dental lamellae, different foramen and deltidial plates and completely different cardinalia. Later, in 1927 Thomson (p. 157) placed *Hemithyris sladeni* in his genus *Aetheia* but it is not at home in this category.

Rhytirhynchia differs from *Aetheia* in the nature of the foramen and deltidial plates, the latter having a minute apical foramen and concave deltidial plates while the other has a fairly large pedicle opening and the deltidial plates are convex. The muscle field in the pedicle valve of *Aetheia* is large but that of *Rhytirhynchia* is small. In the brachial valve the differences between the two genera are still more striking. The cardinalia of *Aetheia* are swollen and united medially and the median ridge is much thickened and ponderous. In *Rhytirhynchia* on the other hand the cardinalia are not overgrown and no median ridge or septum is present.

Rhytirhynchia differs from *Basiliola* in the nature of the folding, details of the deltidial plates and beak, and in the absence of the prominent flat hinge plates in the cardinalia.

Rhytirhynchia sladeni (Dall) is known from seven specimens taken south of the Saya de Malha banks in the Indian Ocean and from *R. hataiana* Cooper n. sp. from Okinawa. A related form appears in the Eocene of the United States but its folding and beak characters are sufficient to establish it as a distinct genus of the same family. *Rhytirhynchia sladeni* was taken at a depth of 123 to 153 fathoms, but the bottom conditions were not reported. Although the specimen in the National Museum is smooth and clean it is reported (Dall, 1910, p. 439) that the brachiopods collected on the Sealark Expedition were encrusted with patches of worm-tubes, Bryozoa and sessile Foraminifera.

Rhytirhynchia hataiana Cooper, n. sp.

Plate 1, figures 1–16

Shell small, subtriangular to subpentagonal in outline; posterolateral margins forming an angle of about 85°; sides strongly rounded; anterior margin truncated; valves unequal in depth, the brachial valve having the greater depth; greatest width at about the middle; anterior commissure sulcificate; surface smooth except for the short and abrupt anterior costation.

Pedicle valve gently and evenly convex in lateral profile; anterior profile broadly and flatly convex; beak bluntly pointed, nearly straight; foramen small, circular, mesothyrid; symphytium elongate; umbo narrowly rounded; median region gently inflated; sulcus

originating in the anterior third and extending onto a short truncated tongue.

Brachial valve moderately convex in lateral profile, more convex than the pedicle valve; anterior profile forming a round dome; umbonal and median regions strongly inflated, with steep sides and umbonal slopes; median fold defined only at the anterior.

Interior.—Pedicle valve with strong, elongate teeth supported by receding, vestigial dental plates; other details obscure. Brachial valve without a cardinal process; socket ridges slender, outer hinge plates moderately broad and nearly flat; crural bases slender; crura short and broad, blunt, concave inward.

Measurements, in millimeters

| Specimen | Length | Brachial length | Midwidth | Thickness |
|--------------|--------|-----------------|----------|-----------|
| 549307----- | 8.9 | 7.9 | 7.9 | 5.4 |
| 549308a----- | 9.7 | 8.8 | 8.7 | 6.1 |
| 549308b----- | 8.7 | 7.8 | 7.9 | 5.1 |
| 549311a----- | 8.2 | 7.4 | 7.3 | 5.2 |
| 549311b----- | 8.6 | 7.7 | 7.3 | 5.3 |

Types.—Holotype USNM 549307 (separated valves of the same specimen); figured paratypes USNM 549308a, 549311b; unfigured paratypes USNM 549308b, 549311a.

Horizon and locality.—Naha limestone, USGS 17504, 17516, 17519, 17572, 17669; USNM (Cooper) 901. Yontan limestone, USGS 17658.

Discussion.—This little species suggests a miniature *R. sladeni* but other differences besides size can be seen. The beak of the pedicle valve of *R. hataiana* is more attenuated and the valve more triangular giving the species a more pentagonal or crudely triangular form than that of *R. sladeni* which is nearly circular. The anterior folding of the Okinawa species is not quite so pronounced as that of *R. sladeni*. The pedicle valve of the Okinawa species is deeper than that of the Indian Ocean species and the valves are thus less disproportionate in depth in *R. hataiana*, although the brachial valve is, nevertheless, much the deeper of the two.

Inside the pedicle valve the dental plates are somewhat more distinct in *R. hataiana* than in the modern species but this might be expected in the geologically older species. In the cardinalia of the Okinawa species the hinge plates separating the socket ridges and crural bases are wider than those of *R. sladeni*. However, the valves of *R. sladeni* are those of an old individual and are thickened by adventitious deposits.

The name of this pretty little species is given in honor of Dr. Kotori Hatai who has made great contributions to our knowledge of Japanese and Pacific brachiopods.

Superfamily Terebratulacea Waagen 1883

Family Cancellothyridae Thomson 1926

Terebratulina japonica (Sowerby)

Terebratula japonica Sowerby. Proc. Zool. Soc., p. 91, 1846

Terebratulina japonica (Sowerby). Davidson, Trans. Linnean

Soc., ser. 2, v. 4, pt. 1, p. 34, pl. 13, figs. 4–11, 1886; Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 225, figs. 14, 16, 1940.

Terebratulina japonica (Sowerby) is characterized by its slender, elongate form and its sharp costellae. A few specimens in the collection from Okinawa are referable to this species but most of them are crushed or otherwise deformed and not suitable for illustration.

Horizon and locality.—Naha limestone (basal sand), USGS 17482 (b, c).

Naha limestone, USGS 17461.

Discussion.—*Terebratulina japonica* has a surprisingly wide toleration of temperature range and bottom types. The species has been found in waters (Hatai 1940, pp. 227–228) ranging in temperature from 2° to 23.3° C and on bottoms ranging from, through various grades of sand to gravel, rocks and coral. The depth range is from 8 to 169 fathoms. With such a wide range of tolerance to various conditions the species proves to have little use in indicating past ecological conditions.

Terebratulina perplexa Cooper, n. sp.

Plate 2, figures 1–17

Fairly large for the genus, elongate-oval in outline; valves of subequal depth; greatest width anterior to the middle in the adult; sides rounded; anterior margin subtruncate; anterior commissure uniplicate; lateral commissure curved anteriorly, convex toward the pedicle valve. Surface marked by strong costellae at the beaks of both valves, but anteriorly the costellae become subdued and flattened about 18 in 5 millimeters near the front margin, appearance of a smooth shell.

Pedicle valve strongly convex in lateral profile with the maximum convexity at about the middle; anterior profile moderately convex with short steep sides; beak truncated, foramen large; umbonal and median regions swollen; anterior half flattened and sulcate; sulcus broad and shallow, producing a short, broadly rounded tongue; sides narrowly rounded and steep.

Brachial valve gently convex in lateral profile and with the maximum convexity at the middle; anterior profile narrowly domed and steep sided; median region from unbo to anterior margin swollen to form an ill-defined fold, seen best at the anterior margin.

Measurements, in millimeters

| Specimen | Length | Brachial length | Midwidth | Maximum width | Thickness |
|--------------|--------|-----------------|----------|---------------|-----------|
| 549320----- | 25.2 | 23.0 | 19.0 | 19.8 | 15.8 |
| 549293a----- | 19.9 | 18.0 | 14.0 | 14.0 | 11.2 |
| 549293b----- | 21.9 | 19.2 | 16.6 | 16.9 | 13.7 |

Types.—Holotype USNM 549320; figured paratypes USNM 549293a, b.

Horizon and locality.—Naha limestone, 17488. USGS 17518, 17519, 17618, 17624, 17630, 17669; USNM (Cooper) 901. Yontan limestone (upper bed), USGS 17656.

Discussion.—The holotype of this species is a large, fairly well-preserved specimen. Its most unusual feature is the fact that the deltidial plates, rather than being discrete as usual in the genus, unite medially. The union of the deltidial plates is a constant feature of the terebratulid genus *Cancellothyris* and this appears to be the only character that differentiates it from *Terebratulina*. I hesitate to use the name *Cancellothyris* because none of the other large *Terebratulinas* in the collection preserves the deltidial plates as well as this one. The few that have them are discrete but they are all younger shells than the holotype. One large shell (USNM 549293b) does not have the deltidial plates preserved. Inasmuch as the foramen of the Okinawa shell is not labiate as in *Cancellothyris* it has been referred to *Terebratulina*.

Terebratulina perplexa is unlike any other described species in the Pacific region in its great depth and the subdued character of its ornamentation. It is most like *T. peculiaris* Hatai but differs in the greater thickness, somewhat more attenuated beak, and the subdued ornamentation of the body of the shell. It agrees in ornamentation with *T. peculiaris* in the presence of strong, obscurely granulated costellae on the umbones of both valves but anteriorly the bifurcated and intercalated costellae are low, flattened, crowded and the striae between the costellae are narrower than the costellae, giving the appearance of an anteriorly smooth shell.

Terebratulina subcarinata Cooper, n. sp.

Plate 2, figures 18–26

Shell small for the genus, elongate-oval in outline; sides broadly rounded; anterior margin narrowly rounded; anterior commissure narrowly uniplicate; surface strongly costellate, about four costellae to the millimeter at the anterior margin.

Pedicle valve moderately convex in lateral profile; anterior profile gently and broadly convex but with the median part slightly depressed; foramen and deltidial plates as usual in the genus. Umbo gently swollen; sulcus narrow and shallow, originating just anterior to the umbo; flanks bounding sulcus gently inflated but narrow.

Brachial valve gently convex in lateral profile; broadly and fairly strongly convex in anterior profile; umbo and median regions swollen, the swelling extending to the anterior margin as a fold commonly somewhat keeled, less commonly inconspicuous; flanks with moderately steep slopes to the margins.

Measurements, in millimeters

| Specimen | Length | Brachial length | Maximum width | Thickness |
|--------------|--------|-----------------|---------------|-----------|
| 549292a----- | 8.4 | 7.2 | 6.6 | 4.3 |
| 549292b----- | 9.8 | 8.4 | 7.9 | 5.0 |
| 549292c----- | 9.1 | 8.1 | 7.8 | 4.9 |
| 549737a----- | 10.8 | 9.2 | 8.9 | 5.6 |

Types.—Holotype USNM 549292a; figured paratype USNM 549337a; unfigured measured paratypes USNM 549292b, c; unfigured paratypes USNM 549337b, c.

Horizon and locality.—Shinzato tuff, locality 17458. Nakoshi sand, USGS 17601. Naha limestone, USGS 17488, 17497, 17499, 17517, 17519, 17534, 17560, ?17575, 17582, 17583, 17606, 17624, 17630, 17671, USNM (Cooper) 901. Yontan limestone, USGS 17586, 17591, 17593, 17644, 17686.

Discussion.—This is a small species usually about 10 millimeters in length. It is also usually strongly costellate and more or less strongly keeled on the brachial valve. It is thus unlike any of the described Japanese *Terebratulinas*. It is suggestive of some forms of *T. reevei* Dall from the Philippines which are strongly costellate and strongly keeled. These are also provided with strongly beaded costellae and thus suggest the genus *Surugathyris*. They are however, unlike the Okinawa species in form because they are more strongly keeled and have distinct posterolateral shoulders.

The Philippine keeled forms referred to *T. reevei* appear to be incorrectly placed because the type specimen (USNM 111064) of that species is an elongate form, finely costellate and without a keel. It is considerably longer and larger than the keeled specimens which probably are an undescribed species.

Terebratulina sp. 1

Plate 2, figures 27–36

Small for the genus, longer than wide, oval in outline; greatest width anterior to the middle; pedicle valve slightly deeper than the brachial valve; anterior commissure uniplicate; surface finely costellate, the costellae narrowly elevated, rounded and separated by striae narrower than the costellae.

Pedicle valve fairly strongly convex in lateral profile, most convex in the umbonal region; anterior profile strongly domed; umbonal and median regions swollen; sulcus originating near midvalve, narrow and shallow; flanks moderately swollen and with moderately steep sides. Beak as usual for the genus.

Brachial valve moderately convex in lateral profile and with the maximum convexity just posterior to the middle; anterior profile somewhat narrowly domed but not so strongly as the pedicle valve; median region strongly swollen with steep lateral slopes but a long and moderately steep anterior slope.

Measurements, in millimeters

| Specimen | Length | Brachial length | Maximum width | Thickness |
|--------------|--------|-----------------|---------------|-----------|
| 549321a----- | 12.5 | 10.5 | 9.7 | 7.4 |

Types.—Figured specimens USNM 549321a, b.

Horizon and locality.—Naha limestone, USGS 17460, 17572, 17635.

Discussion.—These specimens suggest small examples of *T. perplexa* but are more strongly costellate than that species. In comparing these with species figured by Hatai (1940) I am unable to find a satisfactory

niche for them. They are not sufficiently elongate for *T. japonica* (Sowerby) and they are not properly proportioned for reference to *T. peculiaris* Hatai. The unusual thickness prevents assignment to any other species listed by Hatai (1940).

Terebratulina indeterminate

Terebratulina is the commonest of the brachiopods on Okinawa but most of the specimens were too poorly preserved for specific identification. The following localities yielded unidentifiable specimens: USGS 17458, 17482 b and c, 17521, 17543, 17572, 17580, 17583, 17586, 17611, 17649.

Family TEREBRATULIDAE Gray 1840

Gryphus hanzawai Yabe and Hatai

Plate 3, figures 32-39

Gryphus hanzawai Yabe and Hatai. Japanese Jour. Geology, Geography, Trans. and Abs., v. 12, nos. 3-4, p. 96, pl. 14, figs. 4, 5, 8-10, 1935; Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 257, pl. 5, figs. 60-62, 1940.

Small for the genus; elongate-oval in outline with the sides gently rounded but the anterior margin narrowly rounded; greatest width slightly anterior to the middle; anterior commissure rectimarginate; lateral commissure straight; valves of unequal depth, the pedicle valve having the greater depth; surface smooth.

Pedicle valve moderately convex in lateral profile but narrowly rounded in anterior profile; beak somewhat elongated, suberect; foramen small, round, permesothyrid; symphytium concave, not obscured by the beak; median region from beak to base strongly swollen; sides steep.

Brachial valve evenly and gently convex in lateral profile; moderately domed in anterior profile but not quite so strongly convex as the pedicle valve; all parts of valve swollen but sides short and steep.

Interior.—Pedicle valve without dental plates but with stout teeth. Brachial valve with short, narrow, parallel-sided loop with broad transverse ribbon; hinge plates, triangular, fairly broad and slightly concave.

Measurements, in millimeters

| Specimen | Length | Brachial length | Maximum width | Thickness |
|-------------|--------|-----------------|---------------|-----------|
| 549312----- | 9.9 | 8.5 | 6.8 | 6.3 |

Types.—Figured hypotypes USNM 549312, 549338.

Horizon and locality.—Naha limestone, USGS 17484, 17504, 17519, 17572, 17609, 17669, USNM (Cooper) 901.

Discussion.—This is a most unusual species of *Gryphus* because of its small size and elongate, slender form. The species suggests the small *Campages nipponensis* (Y. and H.) with which it occurs. However, it has a straighter beak and no median septum can be seen through the shell.

A fragmentary specimen (USNM 549338) in the

Geological Survey collection had the brachial valve stripped away to show the terebratulid loop from the dorsal side, thus confirming the determination by Yabe and Hatai (1935). The species was reported by these authors from the Ryūkyū limestone of the Plateau above Kamikatetu, Island of Kikai, in the Ryūkyū Islands.

Gryphus stearnsi (Dall and Pilsbry)

Plate 2, figures 37-55

Terebratula stearnsi Dall and Pilsbry. Proc. Acad. Nat. Sci., Philadelphia, p. 165, pl. 4, figs. 1-3, 1891.

Gryphus stearnsi (Dall and Pilsbry). Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 260, pl. 1, figs. 1-4, 7-10, 18, 19, 1940.

Large, oval in the young (see figs. 42-46) but triangular in outline in the adult; valves of unequal depth, the pedicle valve having the greater depth sides nearly straight; anterolateral extremities narrowly rounded; anterior margin broadly rounded; greatest width in the anterior third; anterior commissure faintly and broadly uniplicate; lateral commissure broadly curved toward the brachial valve except anteriorly where it is narrowly curved toward the pedicle valve; surface marked only by concentric lines of growth usually concentrated in the anterior region.

Pedicle valve moderately and evenly convex in lateral profile with the greatest convexity in median region; anterior profile with median region convex but with sides short and dropping precipitately to the margins; beak narrow, suberect, strongly labiate; foramen round, fairly large, permesothyrid; umbo narrowly rounded, median regions gently inflated the slight swelling extending to the front margin; sides short and steep.

Brachial valve gently and evenly convex in lateral profile; anterior profile broadly and moderately domed; umbo narrow; median region from umbo to anterior margin gently inflated; sides descending by gentle slopes to the margins.

Interior.—Pedicle interior not seen in specimens from Okinawa. Brachial interior with small transverse cardinal process and short, narrow, stout loop. Cardinalia with slender and moderately elevated socket ridge; outer hinge plate broad and moderately concave; crural bases low; crural process short, pointed; descending lamellae short; transverse ribbon broad not elevated but with a narrow median carina.

Measurements, in millimeters

| Specimen | Length | Brachial length | Midwidth | Maximum width | Thickness |
|--------------|--------|-----------------|----------|---------------|-----------|
| 549305a----- | 35.6 | 32.2 | 21.8 | 25.9 | 18.2 |
| 549305b----- | 26.7 | 24.2 | 18.7 | 19.9 | 13.5 |
| 549306a----- | 42.8 | 36.9 | ? | 32.9? | 19.7? |
| 549306b----- | 33.1 | 30.9 | 22.8? | 25.5 | 18.2 |

Types.—Figured hypotypes USNM 549305a, b, 549306a, b, 549336.

Horizon and locality.—Shinzato tuff, USGS 17458, 17480 (or Chinen sand). Chinen sand, USGS 17729. Naha limestone, USGS 17475.

Discussion.—All of the specimens of this species except a young one are crushed but all seem to be typical, having the elongate triangular form characteristic for the species. This is the first report of the species in fossil condition.

In modern seas this species, according to Hatai (1940, p. 261), is found from the west coast of Kyûsyû north to Sagami Bay in the Pacific and also in the Korea Strait. The bathymetric range given by Hatai for *G. stearnsi* is 55 fathoms to 103 fathoms and the temperature range is 12.1° C. to 14.8° C. The bottom in the few instances in which this information is recorded is sand and gravel.

Gryphus sp.

A single broken brachial valve without median septum but only with traces of the hinge plates is clearly referable to this genus. It is impossible to place this fragment specifically but it is quite unlike either *Gryphus* described herein. Thus a third species is indicated.

Types.—Described specimen USNM 549342.

Horizon and locality.—Shinzato (?) tuff or Chinen sand, USGS 17480.

Superfamily TEREBRATELLACEA Allan 1940

Family DALLINIDAE Beecher, 1893

Frenulina sanguinolenta (Gmelin)

Plate 3, figures 1-12

Anomia sanguinea Gmelin. Linn. Systema Naturae, ed. 13, v. 1, p. 3347, 1790.

Frenulina sanguinolenta (Chemnitz). Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 327, pl. 4, figs. 42, 44-47, 49, 50, 52-54, 1940.

Small, length and width nearly equal; rhomboidal to pentagonal in outline; posterolateral margins nearly straight, meeting to approximate a right angle; sides narrowly rounded; anterior margin rounded; anterior commissure sulcate; valves unequally convex, the pedicle valve having the greater convexity; surface smooth or marked by concentric growth lines and lamellae.

Pedicle valve moderately convex in lateral profile, fairly strongly convex in anterior profile; beak incurved, truncated, suberect; foramen large, mesothyrid; symphytium entire; umbo swollen, the swelling continued anteriorly as a ridge or fold to the front margin; flanks flattened and descending steeply to the margins.

Brachial valve gently convex in lateral profile, broadly and gently convex in anterior profile; umbo and

median regions swollen but anterior third flattened or depressed to form a shallow sulcus; tongue of brachial valve short and rounded; flanks bounding sulcus moderately swollen.

| Specimen | Measurements, in millimeters | | | |
|-------------|------------------------------|-----------------|---------------|-----------|
| | Length | Brachial length | Maximum width | Thickness |
| 549334----- | 8.8 | 7.6 | 8.0 | 5.7 |
| 549333----- | 8.5 | 7.4 | 8.2 | 4.9 |

Types.—Figured hypotypes USNM 549333, 549334.

Horizon and locality.—Yontan limestone, USGS 17544, 17646, 17686. Naha limestone, USGS 17582, 17606.

Discussion.—This genus may be recognized by its small size and the sulcation of the anterior commissure. The specimens herein described are not well preserved and are somewhat exfoliated but seem to be characteristic of the species. Compared with modern specimens the degree of sulcation seems to be somewhat less and the sulcus somewhat broader but these are variable features.

This genus is one of the most widespread of modern Pacific brachiopods. In modern waters it can be recognized by its anterior sulcation and by the beautiful subradial dark red striping of the shells. It is known from the Hawaiian Islands to the Celebes.

Campages nipponensis (Yabe and Hatai)

Plate 3, figures 15-31

Japanithyris nipponensis Yabe and Hatai. Japanese Jour. Geology, Geography, Trans. and Abs., v. 12, nos. 3, 4, p. 98, pl. 14, figs. 1-3, 19-21, 1935; Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 314, pl. 5, figs. 5, 6; pl. 7, figs. 1-4, 1940.

Shell small for the genus, longer than wide; elongate-oval in outline; sides gently rounded; anterior margin narrowly rounded; greatest width just anterior to the middle; valves of unequal depth, the pedicle valve having the greater depth; anterior commissure faintly intraplicate; surface smooth or marked by overlapping concentric lamellae.

Pedicle valve strongly convex in lateral profile and with the maximum convexity at about the middle; anterior profile narrowly domed; sides precipitous; beak short, truncated, suberect; foramen fairly large, round, permesothyrid, labiate; umbo narrowly rounded; median and anterior regions swollen; sulcus defined in the anterior third or quarter, shallow and narrow, causing a dorsad wave in the anterior commissure.

Brachial valve moderately convex in lateral profile, broadly domed in anterior profile; median region moderately swollen; fold low, inconspicuous; flanks bounding fold low; anterolateral extremities pointed.

Interior.—Interior of pedicle valve not known. Brachial interior with slender median septum reaching

anteriorly to beyond midvalve; loop with broad transverse band.

| Specimen | Measurements, in millimeters | | | |
|--------------|------------------------------|-----------------|---------------|-----------|
| | Length | Brachial length | Maximum width | Thickness |
| 549295b----- | 8.4 | 7.2 | 6.2 | 5.6 |
| 549319----- | 9.8 | 8.2 | 6.9 | 7.0 |

Types.—Figures hypotypes USNM 549295a, b, c, 549319.

Horizon and locality.—Nakoshi sand, locality 17599. Naha limestone, USGS 17462, 17463, 17473, 17624, 17641, USNM (Cooper) 901.

Discussion.—This interesting and pretty little species can be recognized by its elongate-oval outline and the broadly but weakly intraplicate anterior commissure. This is a characteristic of the present genus *Japanithyris* to which Yabe and Hatai referred their species, although they had not seen the loop. The Okinawa specimens, in some instances are filled with crystalline calcite, a happy condition that makes it possible to prepare the loop (see pl. 3, figs. 22–24).

Two prepared specimens of this species show the loop of *Campages*, not the type of loop said to belong to *Japanithyris*.

Jolonica hedleyi Dall

Plate 4, figures 33–45

Campages (*Jolonica*) *hedleyi* Dall. Proc. U. S. Natl. Mus., v. 57, p. 366, 1920.

Jolonica hedleyi Dall. Jackson and Stiasny, Brachiopoda of the Siboga Expedition, Siboga-Expeditie, Mon. 27, p. 16, pl. 2, figs. 24–27, 1937.

This species was well described by Dall (1920); it seems unnecessary therefore to repeat the detailed description. Dall however, never figured his species on which he based the genus *Jolonica*. Consequently a full set of figures of the holotype and only specimen of Dall's species is introduced here. This genus is an important one in Pacific waters of today and is proving to be a leading fossil in Pacific Tertiary deposits. Three species of *Jolonica* are reported here from Okinawa. Beside the type another modern species is known from Japanese waters.

Jolonica has a loop similar to that of *Campages* but the exterior form and other interior details are different. Inside the pedicle valve *Jolonica* is provided with strong dental plates but *Campages* has none. The anterior commissure of *Jolonica* is rectimarginate whereas that of *Campages* is broadly intraplicate according to Thomson (1927, p. 249). Inside the brachial valve *Campages* has a complete, concave, hinge plate supported by the median septum, but the hinge-plate of *Jolonica* is divided and the median septum can be seen between the plates.

In modern waters *Jolonica* is known from off Jolo, Philippines, the Malay Archipelago, and off the Japa-

nese Islands. The type species was found on sand in 318 fathoms.

| Specimen | Measurements, in millimeters | | | |
|-------------|------------------------------|-----------------|---------------|-----------|
| | Length | Brachial length | Maximum width | Thickness |
| 111059----- | 18.8 | 16.8 | 18.3 | 9.6 |

Types.—Holotype USNM 111059.

Locality.—Sand, 318 fathoms, off Jolo, Philippines.

Jolonica elliptica Cooper, n. sp.

Plate 3, figures 61–69

Of about medium size for the genus; longer than wide; maximum width at the middle; outline elongate-oval; lateral margins gently rounded; valves of unequal depth, the pedicle valve having the greater depth; anterior margin truncated; anterior commissure rectimarginate to faintly sulcate; surface smooth.

Pedicle valve with moderately convex lateral profile and with the anterior profile narrowly domed; beak incurved, truncated, erect; foramen transversely elliptical, submesothyrid, umbo narrowly swollen, the swelling continuing anteriorly along the valve middle nearly to the front margin; sides steep.

Brachial valve gently convex in lateral profile; broadly and gently convex in anterior profile; median region gently swollen with moderately steep slopes laterally, but a longer and more gentle anterior slope.

Interior.—Pedicle valve with strong and long dental plates; brachial valve with divided hinge-plate and a loop with slender descending branches, the transverse ribbon with prominent rounded notch facing in a dorsal direction and broad bands connecting the transverse ribbon with the descending branches. (For description of immature loop see discussion below.)

| Specimen | Measurements, in millimeters | | | |
|--------------|------------------------------|-----------------|----------|-----------|
| | Length | Brachial length | Midwidth | Thickness |
| 549324c----- | 16.0 | 14.0 | 13.9 | 8.4 |
| 549324a----- | 12.9 | 11.4 | 10.9 | 6.4 |
| 549324b----- | 13.1 | 11.6 | 11.2 | 6.6 |

Types.—Holotype USNM 549324c; figured paratype USNM 549324a; unfigured paratypes USNM 549324b, d-g; figured specimen USNM 549335.

Horizon and locality.—Naha limestone, USGS 17460, 17462, 17463, 17582.

Discussion.—This species is characterized by its elongate form, transversely elliptical foramen, and a loop with a rounded notch in the transverse ribbon. In these respects it differs from all other species of the genus.

Three features of this species are unusual: (1) the elongate form is only like that of *J. ryukyuensis* Y. and H. (the type species is nearly circular); (2) the foramen is elliptical rather than circular as in other species; and (3) the loop is more slender and delicate than in the

other species and the notch is rounded, not angular as in the type and *J. ryukyuensis*.

A small specimen, USNM 549335, with pedicle valve partially stripped away is assigned doubtfully to this species. The loop revealed shows descending lamellae attached to a divided hinge plate posteriorly and the median septum anteriorly. The median septum does not extend posteriorly to the hinge-plate. At the anterior a narrow hood is supported by the septum and descending lamellae. The general form of the specimen leads to its tentative association with *J. elliptica*. Although the complete loop development of *Jolonica* is unknown this specimen may represent one of the early stages.

***Jolonica ryukyuensis* Yabe and Hatai**

Plate 4, figures 1-17

Jolonica ryukyuensis Yabe and Hatai. Japanese Jour. Geology, Geography, Trans. and Abs., v. 12, nos. 3, 4, p. 97, pl. 14, figs. 6, 7, 14, 1935; Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 7, figs. 28, 33, 39, 1940.

Large for the genus, elongate oval in outline; valves of unequal depth, the pedicle valve having the greater depth; sides broadly rounded; anterior narrowly rounded; greatest width at the middle; anterior commissure rectimarginate; lateral commissure straight; surface marked only by concentric lines of growth.

Pedicle valve with moderately and evenly convex lateral profile with the most convex part in the middle; anterior profile strongly domed and steep sided; beak large, moderately long, incurved, suberect to erect in old specimens; foramen large, circular, mesothyrid to permesothyrid; beak ridges strong, meeting the anterior half of the foramen; symphytium prominent, in some instances longitudinally corrugated; umbo narrowly swollen, the swelling continued anteriorly to the front margin in some specimens but terminating near the front in others. Sides and anterior slope steep.

Brachial valve moderately convex in lateral profile, with the maximum convexity slightly posterior to the middle; anterior profile broadly and fairly evenly convex, much less convex than the pedicle valve; umbo and median regions inflated; anterior third somewhat flattened.

Interior.—Interior of pedicle valve with small dental plates. Brachial valve with fairly large, prominent cardinal process, strong socket ridges and fairly broad hinge plates; loop long, with slender descending lamellae, but a broad transverse ribbon with rectangular indentation facing the brachial valve.

Measurements, in millimeters

| Specimen | Length | Brachial length | Midwidth | Hinge width | Thickness |
|--------------|--------|-----------------|----------|-------------|-----------|
| 549328----- | 20.3 | 17.3 | 16.4 | 8.0 | 12.4 |
| 549290a----- | 18.6 | 16.2 | 15.0 | 6.2 | 11.1 |
| 549325----- | 19.3 | 17.1 | 14.9 | 5.5 | 12.3 |
| 549327----- | 28.5 | 25.0 | 21.5 | 10.2 | 19.9 |

Types.—Figured hypotypes USNM 549290, 549325-549328.

Horizon and locality.—Chinen sand, USGS 17482. Naha limestone, USGS 17473, 17497, 17517, 17519, 17572, 17583, 17618, 17624, 17628, 17661, ? 17669, 17670, USNM (Cooper) 901.

Discussion.—This species is characterized by its elongate-oval outline, robust valves, considerable depth and large size. Yabe and Hatai (1935, p. 97) defined the species from a single fragment but this showed the generic characters very clearly and the fact that it was a large species. Specimens from several localities on Okinawa clearly belong to this species and give opportunity to redefine the species and figure nearly all of its details. It attains an unusually large size for the genus and is also unusual for its elongate form and great thickness.

***Jolonica macneili* Cooper, n. sp.**

Plate 4, figures 18-32

Small for the genus, elongate oval in outline; widest at the middle; sides rounded; anterior margin broadly rounded in the adult; anterior commissure rectimarginate; lateral commissure straight; surface smooth except for concentric growth lines and lamellae.

Pedicle valve moderately convex in lateral profile with the umbonal region narrowly rounded; anterior profile strongly convex; beak short, suberect; foramen round, mesothyrid; beak ridges strong, intersecting the foramen at its middle; median region strongly swollen; lateral slopes steep.

Brachial valve broadly convex in lateral profile, much less convex than the pedicle valve; postero-median region inflated; anterior portion somewhat flattened.

Interior.—Pedicle interior with small dental plates, short thick median ridge and elongate divergent diductor scars. Brachial valve with small cardinal process and delicate cardinalia; hinge plates small, septum slender, abruptly terminated anteriorly, not meeting the cardinal process posteriorly.

Measurements, in millimeters

| Specimen | Length | Brachial length | Midwidth | Hinge width | Thickness |
|--------------|--------|-----------------|----------|-------------|-----------|
| 549323d----- | 12.5 | 10.8 | 11.1 | ----- | 5.9 |
| 549313a----- | 13.2 | 11.5 | 12.3 | 7.5 | 7.2 |
| 549323a----- | 15.1 | 13.4 | 14.3 | 9.5? | 6.8+ |
| 549323d----- | 17.0 | 14.9 | 14.2 | ? | 6.9+ |

Types.—Holotype USNM 549323d; figured paratypes USNM 549313a, 549323a, c; unfigured paratypes USNM 549313b, 549323b, e.

Horizon and locality.—Yonabaru clay, USGS 17445. Shinzato tuff, USGS 17453, 17633. Chinen sand, USGS 17482.

Discussion.—This species is quite different from *J. ryukyuensis* and is more suggestive of *J. hedleyi*. It differs from *J. ryukyuensis* in its smaller size, more slender profile, and less robust form.

Jolonica macneili is a more slender and smaller species than *J. hedleyi* and is also proportionately somewhat longer.

Differences between the two species are apparent inside the valves. The elongate diductor scars of the pedicle valve are more deeply impressed in *J. macneili* despite the fact that it is the smaller species and the median ridge is more strongly developed. Inside the brachial valve the hinge plates attaching the socket ridges to the crural bases are wider in the Okinawa shell than in the modern form.

In selecting the holotype of *J. macneili* it seemed best to choose a specimen showing the interior details. Consequently the one selected has the matrix cleaned out of both valves. Thus the interior of the holotype is known except for the loop. The anterior margin of the holotype is not well preserved; consequently the measurements of length of both valves is approximate. This is the oldest known species of the genus.

This species is named in honor of F. Stearns MacNeil of the Geological Survey.

***Dallina raphaelis* (Dall)**

Plate 3, figures 46–49

Waldheimia raphaelis Dall. Am. Jour. Conch., v. 6, p. 111, pl. 7, figs. a–e, 1870.

Dallina raphaelis (Dall). Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 316, pl. 1, figs. 15, 20, 21, 28; pl. 6, figs. 79–84; pl. 7, figs. 5, 10, 15, 1940.

Two specimens, both juveniles, are the only examples of this species in the collection from Okinawa. The species can be readily recognized by its subtriangular outline, broadly intraplicate anterior commissure and the long slender septum in the brachial valve. The septum extends from the beak anteriorly for fully $\frac{3}{4}$ the length of the individual. This is a thin-shelled brachiopod; both specimens are crushed. The largest of the two specimens is 16 mm long, 12 mm wide near the anterior, and 8 mm thick.

Type.—Figured hypotypes USNM 549316a, b.

Horizon and locality. Shinzato (?) tuff or Chinen sand, USGS 17480.

Family Laqueidae Thomson, 1927

***Laqueus quadratus* Yabe and Hatai**

Plate 3, figures 50–53

Laqueus quadratus Yabe and Hatai. Proc. Imp. Acad. Tokyo, v. 10, no. 10, p. 662, text figs. 10–13, 15, 1934; Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 356, pl. 3, figs. 32–35, 42, 43; pl. 5, figs. 20–22; pl. 8, figs. 57, 58, 65, 1940.

Shell about medium size for the genus; subquadrate in outline with the sides gently rounded and the anterior

margin truncated; pedicle valve deeper than the brachial valve; anterior commissure rectimarginate(?); greatest width slightly posterior to the middle; surface smooth except for concentric lines of growth.

Pedicle valve with lateral profile gently convex; anterior profile broadly and moderately convex; beak suberect; foramen small circular, permesothyrid; symphytium completely exposed; umbonal and median regions strongly convex; sides steep.

Brachial valve gently convex in lateral profile and broadly but slightly convex in anterior profile; median region somewhat swollen; sides descending gently to the lateral margins.

Interior.—Pedicle interior not known except for dental plates visible through shell. Brachial valve with delicate cardinalia; hinge plate gently concave and supported by a slender median septum reaching almost to midvalve; postero-median part of hinge plate marked by a deep groove extending to the beak.

| Specimen | Measurements, in millimeters | | | |
|--------------|------------------------------|-----------------|---------------|-----------|
| | Length | Brachial length | Maximum width | Thickness |
| 549318a----- | 17+ | 15+ | 18.3? | ? |
| 549318b----- | 17.8 | 15.5 | 15.7? | ? |

Types.—Figured hypotypes USNM 549318a–c.

Horizon and locality.—Shinzato (?) tuff or Chinen sand, USGS 17480. Naha limestone, USGS 17463.

Discussion.—This species can be recognized by its square to somewhat longitudinally rectangular form. The interior is distinguished by the presence of dental plates in the pedicle valve, a concave hinge plate supported by the median septum in the brachial valve. All of the specimens are severely crushed.

***Laqueus elongatus* Cooper, n. sp.**

Plate 3, figures 40–45

Small for the genus, elongate-oval in outline; valves unequal in depth the pedicle valve the deeper; sides broadly rounded; anterolateral extremities narrowly rounded; anterior margin broadly rounded; greatest width at the middle; anterior commissure rectimarginate; surface marked only by concentric lines of growth.

Pedicle valve moderately convex in lateral profile with the maximum convexity located slightly posterior to the middle; anterior profile narrowly and strongly convex and with steeply sloping sides; beak small, pointed, suberect; foramen small, telate, permesothyrid; umbonal and median regions somewhat narrowly swollen; anterior third flattened and forming a long moderately steep slope; lateral slopes short and steep.

Brachial valve gently convex with the maximum curvature posterior to the middle; anterior profile broadly and moderately convex; umbonal and median

regions swollen; anterior third somewhat flattened; sides with moderately steep slopes.

Interior.—Pedicel valve with moderately long dental plates. Brachial valve with concave hinge-plate as usual in the genus.

| Specimen | Measurements, in millimeters | | | |
|-------------|------------------------------|-----------------|----------|-----------|
| | Length | Brachial length | Midwidth | Thickness |
| 549309----- | 14.9 | 13.3 | 10.8? | 8.3 |

Types.—Holotype USNM 549309; unfigured paratypes USNM 549339a-e.

Horizon and locality.—Shinzato tuff, USGS 17458. Naha limestone, USGS 17462, 17463.

Discussion.—This is an unusually small species of *Laqueus* being much smaller than *L. rubellus* (Sowerby) and much differently shaped. *Laqueus suffusus* Dall is larger and subcircular; *L. quadratus* Yabe and Hatai is similar but is larger and squarer in outline; *L. kosibensis* Hatai is elongate and attenuate but it is a larger shell and the maximum width is anterior to the middle rather than at the middle as in *L. elongatus*. This is a rare species in the Tertiary of Okinawa.

Laqueus sp. 1

Plate 3, figures 54-60

Small for the genus, longitudinally subelliptical to suboval in outline; length slightly greater than the width; widest at the middle; sides strongly rounded; posterolateral margins nearly straight forming an angle of about 90° with the beak; anterior commissure rectimarginate; valves subequal in depth; surface marked only by fine concentric lines of growth and strong growth lamellae.

Pedicel valve moderately convex in lateral profile but with the maximum convexity slightly posterior to the middle; anterior profile broadly convex, with long sloping sides; beak small, incurved, suberect; beak small, telate, foramen small and circular, mesothyrid; umbo narrowly swollen, the swelling continuing anteriorly as a narrow fold but lessening on the anterior slope.

Brachial valve moderately convex in lateral profile, broadly domed in anterior profile; median region inflated; umbonal and lateral slopes short and steep; anterior slope long and moderately steep.

Interior.—Pedicel valve with strong dental plates. Brachial valve with strongly elevated socket ridges and deeply concave, undivided hinge plate supported by the high median septum.

| Specimen | Measurements, in millimeters | | | |
|-------------|------------------------------|-----------------|----------|-----------|
| | Length | Brachial length | Midwidth | Thickness |
| 549340----- | 12.0 | 10.6 | 10.6 | 5.7 |

Types.—Figured specimen USNM 549340.

Horizon and locality.—Naha limestone, USGS 17505.

Discussion.—This little species was found with specimens of *Pictothyris* and was at first mistaken for a young specimen of *P. picta*. It was only through the fortunate preparation of the interior of the specimen that its generic affinities were discovered. This specimen was at first thought to be the young of *L. rubellus*, but specimens of that species having a size comparable to the Okinawa specimen, have a much larger foramen and beak and have a different outline.

The exterior of the Okinawa shell suggests *L. concentricus* Yabe and Hatai but that species is larger and has a different outline. The shape and exterior surface of *L. orbicularis*, another species of small size, are unlike those of the Okinawa specimen. *Laqueus pacificus* Hatai is another small *Laqueus* but it is elongate-oval and quite different from the *Laqueus* from Okinawa. I know of no other species of small size to which this one may be compared.

This *Laqueus* is represented by a single specimen and is not named here because it may be the young of a larger species and because of the difficulty of separating it from young *Pictothyris*. It seems to have no exterior characters except the small, telate beak which will separate it from *Pictothyris*.

Pictothyris picta (Dillwyn)

Plate 5, figures 1-18

Anomia picta Dillwyn. Cat. Recent Shells, v. 1, p. 295, 1817. *Pictothyris picta* (Dillwyn). Thomson, Brachiopod Morphology and Genera (Recent and Tertiary), New Zealand Board Sci. Art., Manual 7, p. 260, 1927; Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 369, 1940.

Shell of moderate size, longitudinally elliptical to oval in outline; sides broadly rounded; anterior margin narrowly rounded; valves of subequal convexity; anterior commissure rectimarginate; lateral commissure straight; surface marked only by concentric lines of growth.

Pedicel valve with fairly even and moderate convexity in lateral profile; anterior profile strongly and somewhat narrowly convex and with steep sides; beak incurved, suberect; foramen moderately large, mesothyrid; beak ridges strong; umbo somewhat narrowly swollen, the swelling continued as a rounded ridge to about the anterior third, and indistinctly thereafter; flanks fairly steep.

Brachial valve fairly evenly convex in lateral profile but with the posterior half somewhat the more convex; anterior profile strongly convex but not so narrowly rounded medially as the pedicel valve; umbonal and median regions inflated; anterior third somewhat flattened; lateral slopes short and steep; anterior slope longer and less steep than the lateral ones.

Interior.—Pedicel valve with stout teeth supported by remnantal dental plates; median ridge stout but low; diductor scars narrow and elongated. Brachial valve with stout cardinalia, cardinal process large and fairly long shafted; median septum short and stout. Loop not attached to septum. Transverse ribbon broad posteriorly indented.

| Specimen | Measurements, in millimeters | | | | |
|--------------|------------------------------|-----------------|----------|-------------|-----------|
| | Length | Brachial length | Midwidth | Hinge width | Thickness |
| 549291----- | 24.0 | 21.6 | 19.6 | 12.3 | 14.2 |
| 549330a----- | 24.0 | 22.1 | 20.0 | 12.6 | 12.4 |
| 549330b----- | 23.2 | 21.4 | 18.5 | 9.5 | 12.2 |
| 549331----- | 22.8 | 21.8 | 19.4 | 9.6 | 11.6 |

Types.—Figured hypotypes, USNM 549330a, b, c, 549331, 549341a.

Horizon and locality.—Naha limestone, USGS 17462, 17484, 17497, 17498, 17505, 17521, 17522, 17524, 17529, 17577, 17583, 17622, 17625, 17628, 17631, 17649; USNM (Cooper) 901. Nakoshi sand, USGS 17600.

Discussion.—This is a fairly common species on Okinawa; none of the specimens examined presents any unusual features. The specimens are slightly smaller than modern representatives of the species. *Pictothyris* is distinguished from *Kikaithyris* by its more slender outline and the less incurved beak with its large foramen. The foramen of *Kikaithyris* is small to minute.

Modern *Pictothyris picta* was collected at 20–80 fathoms (Hatai 1940, p. 370).

Kikaithyris hanzawai (Yabe)

Plate 5, figures 19–49

- Pictothyris hanzawai* Yabe. Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology) v. 15, no. 3, p. 196, pl. 13, figs. 10–16, 1932.
P. hanzawai Yabe. Yabe and Hatai, Japanese Jour. Geology, Geography, Trans. and Abs., v. 12, nos. 3–4, p. 101, pl. 14, figs. 15–17, 1935.
P. hanzawai Yabe. Hatai, Sci. Repts. Tohoku Imp. Univ., ser. 2 (Geology), v. 20, p. 374, pl. 4, figs. 17–21, 31, 32, 1940.
Kikaithyris hanzawai (Yabe). Yabe and Hatai, Jour. Geol. Soc. Japan, v. 48, no. 577, p. 492, 495.

Large, longitudinally elliptical to subpentagonal in outline; greatest width at about the middle; postero-lateral margins nearly straight, medial lateral margins narrowly rounded and anterolateral margins nearly straight and sloping medially; anterior margin narrowly rounded; anterior commissure rectimarginate or with a faint suggestion of sulcation; lateral commissure straight; valves about equal in depth; surface marked by concentric lines of growth, otherwise smooth.

Pedicel valve with lateral profile evenly and gently convex except for the umbo which is narrowly rounded;

anterior profile narrowly humped in the middle but with the sides sloping moderately to the margins. Beak incurved, small, erect; foramen small to minute, mesothyrid; beak ridges strong; umbo narrowly swollen, the swelling continuing anteriorly as a narrow ridge nearly to the front margin where it becomes indistinct, flanks flattened, moderately steep.

Brachial valve somewhat more convex than the pedicel valve in lateral profile and with the maximum convexity in the posterior two-thirds, anterior third somewhat flattened; anterior profile somewhat broadly domed, slightly more convex than the pedicel valve in the same profile and not somewhat carinate as in the other valve; umbonal and median regions swollen; lateral and anterior slopes moderately steep.

Interior.—Pedicel valve with large teeth buttressed by remnantal dental plates; median ridge low and short; diductor scars elongate, narrow. Brachial valve with thickened cardinalia; socket ridges massive and swollen; cardinal process large, median septum short and thick; loop with expanded crural bases, slender descending lamellae and broad transverse ribbon tied to the descending lamellae by broad struts.

| Specimen | Measurements, in millimeters | | | | |
|--------------|------------------------------|-----------------|----------|-------------|-----------|
| | Length | Brachial length | Midwidth | Hinge width | Thickness |
| 549298----- | 33.6 | 31.0 | 29.8 | 17.8 | 17.7 |
| 549299a----- | 29.7 | 27.4 | 26.8 | 16.2 | 16.4 |
| 549299b----- | 27.8 | 25.4 | 23.8 | 15.0 | 15.4 |
| 549301----- | 28.4 | 26.4 | 25.2 | 14.9 | 14.8 |
| 549297----- | 30.7 | 28.3 | 25.7 | 15.1 | 16.0 |
| 549289----- | 29.0 | 26.6 | 22.0 | 14.4 | 14.7 |
| 549302----- | 17.1 | 15.7 | 15.5 | 10.4 | 7.8 |

Types.—Figured hypotypes, USNM 549289, 549297, 549298, 549299a, 549300a, 549301, 549302, 549304.

Horizon and locality.—Nakoshi sand, USGS 17486, 17601. Naha limestone, USGS 17464, 17466, 17484, 17488, 17498, 17517, 17572, 17592, 17604, 17605, 17607, 17609, 17618, 17623, 17630, 17657, 17661, 17669, USNM Cooper 901. Yontan limestone, USGS 17591, 17656, 17658, 17660.

Discussion.—This species is the most easily identified Okinawan brachiopod because of its large size, shouldered outline, and narrow anterior. It is readily distinguished from *Pictothyris* by its outline, the strongly incurved beak, and its minute foramen. This genus is common in the Ryūkyū Islands and is known as far south as Formosa. It is not known in the modern fauna but is characteristic of late Pliocene or early Pleistocene assemblages.

Indeterminate brachiopods

The following localities yielded specimens too poor for generic identification: USGS 17452, 17457, 17497, 17547, 17591, 17614, 17628.

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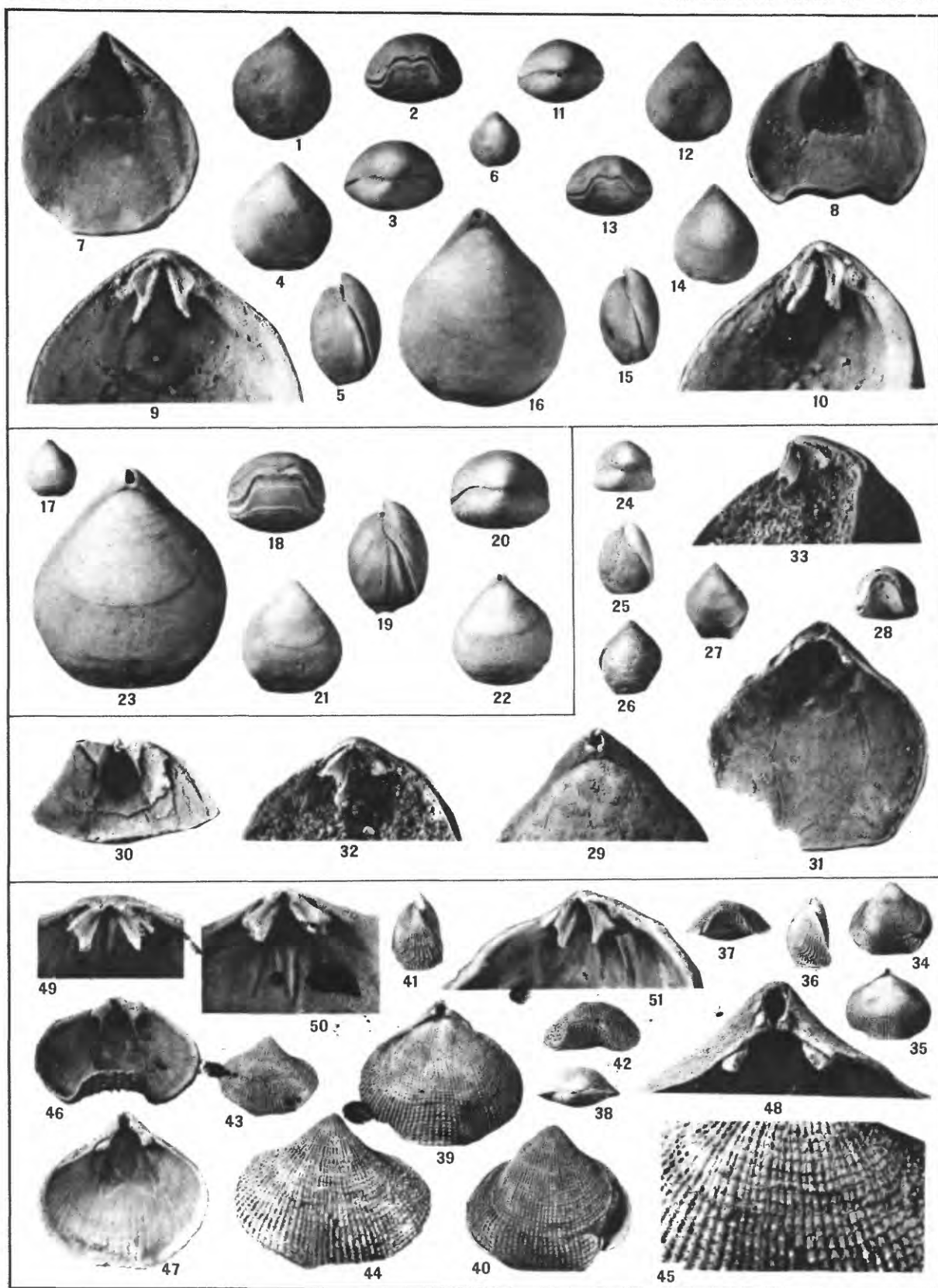
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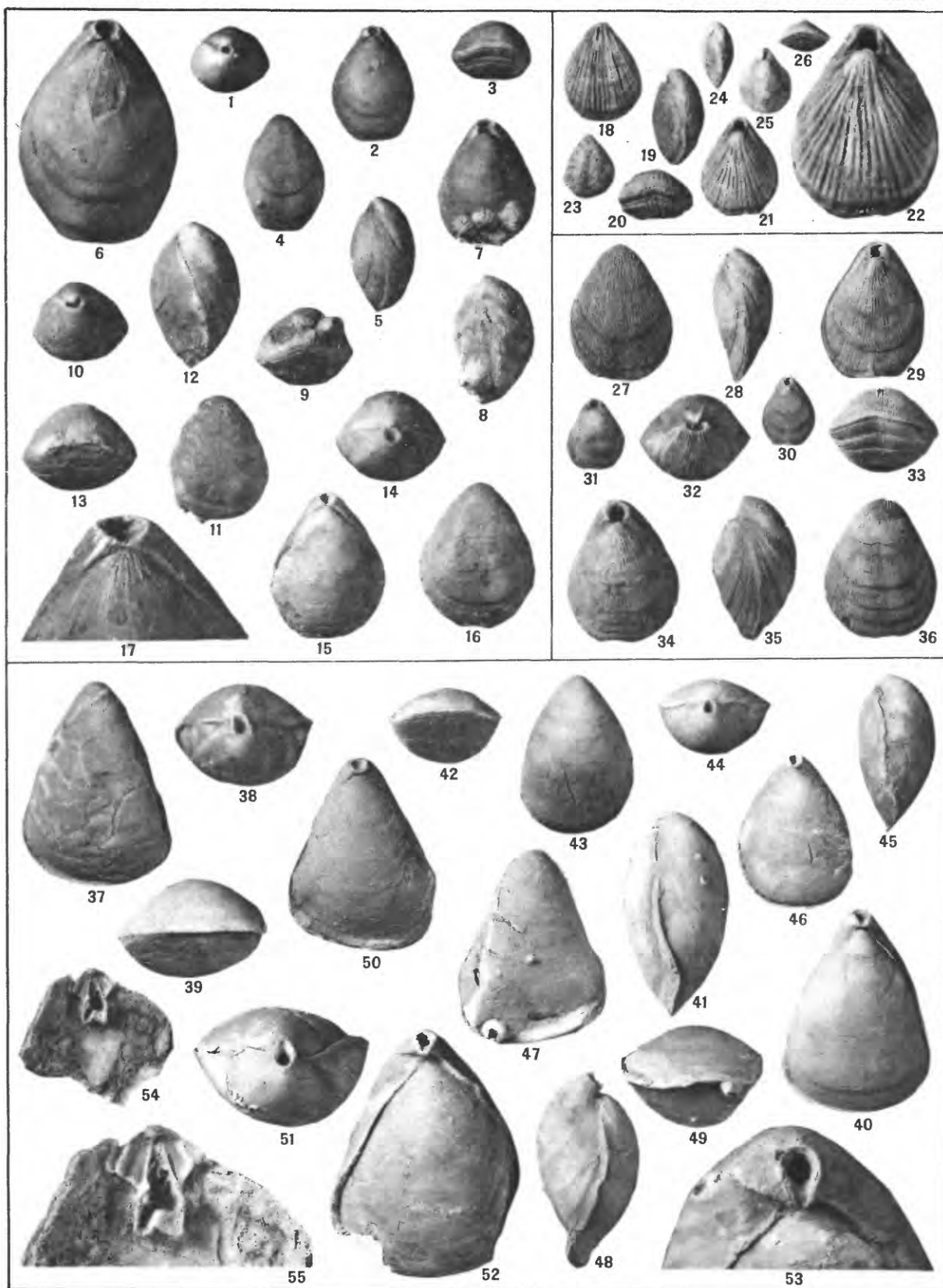
PLATE 1

FIGURES 1-16. *Rhytirhynchia hataiana* Cooper, n. sp. (p. 8)

- 1-5. Respectively brachial, anterior, posterior, pedicle and side views of a large specimen, $\times 2$, paratype USNM 549308a.
6. Brachial view of the same specimen, $\times 1$.
- 7, 8. Interior of the pedicle valve showing muscle field vascula media indistinctly, and the corrugated teeth, $\times 4$, holotype USNM 549307. Fig. 8 tilted to show small, vestigial dental plates.
- 9, 10. Posterior of the interior of the brachial valve of the holotype showing the cardinalia, $\times 6$, fig. 9 in full view, fig. 10 tilted to the side.
Naha limestone, USGS 17572.
- 11-15. Respectively posterior, pedicle, anterior, brachial and side views of another specimen, smaller than the preceding but showing the small round foramen and plicated anterior commissure, $\times 2$, paratype USNM 549311b.
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30. Interior view of a fragmentary pedicle valve tilted to show thin dental plates, $\times 3$, hypotype USNM 549315e.
31. Interior view of another pedicle valve showing corrugated tooth, muscle field and obscure pallial marks, $\times 3$, hypotype USNM 549315d.
32. Posterior part of a brachial interior showing cardinalia with their prominent outer hinge-plates and short crus, $\times 4$, hypotype USNM 549315b.
33. Shinzato(?) tuff or Chinen sand, USGS 17480. Same specimen, $\times 4$, tilted to the side to show concave crus.
- 34-51. *Tegulorhynchia döderleini* (Davidson) (p. 6)
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Shinzato(?) tuff or Chinen sand, USGS 17480.



RHYTIRHYNCHIA, BASILIOLA, AND TEGULORHYNCHIA



TEREBRATULINA AND GRYPHUS

PLATE 2

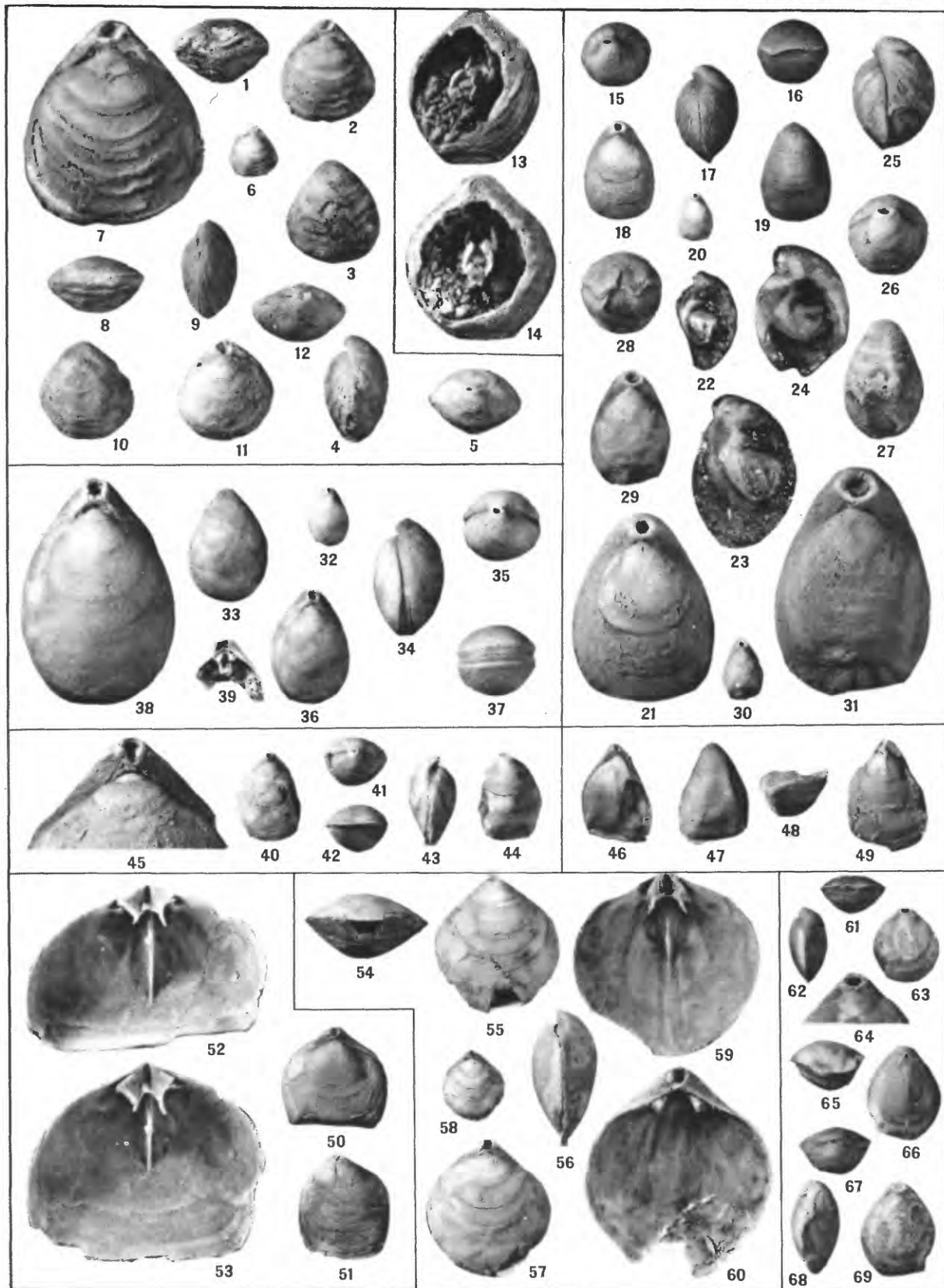
FIGURES 1-17. *Terebratulina perplexa* Cooper, n. sp. (p. 9).

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6. Same, $\times 2$, showing beak region.
- 7-11. Respectively brachial, side, anterior, posterior and pedicle views of a larger specimen, $\times 1$, paratype USNM 549293b.
Naha limestone, USNM (Cooper) 901.
- 12-16. Respectively side, anterior, posterior, brachial and pedicle views of a large, robust specimen, $\times 1$, showing fine, subdued costellae on all parts of shell anterior to umbo, holotype USNM 549320.
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Yontan limestone, USGS 17656.
- 18-26. *Terebratulina subcarinata* Cooper, n. sp. (p. 10).
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Naha limestone, USNM (Cooper) 901.
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Naha limestone, USGS 17475.

PLATE 3

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 - 6, 7. Same specimen, $\times 1$ and $\times 4$.
Naha limestone, USGS 17606.
 - 8-12. Respectively anterior, side, pedicle, brachial, and posterior views of another specimen, $\times 2$, hypotype USNM 549333.
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- 13, 14. *Jolonica?* sp. aff. *J. elliptica* Cooper, n. sp. (p. 13)
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 - 22, 23. Respectively side and tilted views of a specimen with shell stripped away to show loop, $\times 2$, $\times 3$, hypotype USNM 549295a.
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Naha limestone, USNM (Cooper) 901.
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Naha limestone, USGS 17473.
- 32-39. *Gryphus hanzawai* Yabe and Hatai. (p. 11)
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 - 33-37. Respectively pedicle, side, posterior, brachial and anterior views of the preceding specimen, $\times 2$.
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Naha limestone, USGS 17504.
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Naha limestone, USGS 17484.
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50. Brachial view of a flattened individual, $\times 1$, hypotype USNM 549318a.
 51. Pedicle view of another flattened specimen, $\times 1$, hypotype USNM 549318b.
 - 52, 53. Interior of the brachial valve tilted and in normal view, $\times 3$, showing concave hinge-plate supported by the median septum, hypotype USNM 549318c.
Shinzato (?)tuff or Chinen or sand, USGS 17480.
- 54-60. *Laqueus* sp. 1 (p. 16)
- 54-57. Respectively anterior, pedicle, side and brachial views of a nearly perfect specimen, $\times 1$, figured specimen USNM 549340.
 58. Brachial view of the same specimen, $\times 2$.
 - 59, 60. Respectively interior views of the brachial and pedicle valves, $\times 3$, of the same specimen showing concave hingeplate and no ridge in pedicle valve.
Compare with *Pictothyris* (Pl. 5).
Naha limestone USGS 17484.
- 61-69. *Jolonica elliptica* Cooper, n. sp. (p. 13).
- 61-63. Respectively anterior, side and brachial views of a young specimen, $\times 1$, paratype USNM 549324a.
 64. Posterior of preceding, $\times 2$, showing transversely elliptical foramen.
 - 65-69. Respectively anterior, pedicle, posterior, side and brachial views, $\times 1$, of the holotype, USNM 949324c.
Naha limestone, USGS 17460.



FRENULINA, GRYPHUS, CAMPAGES, LAQUEUS, DALLINA, JOLONICA

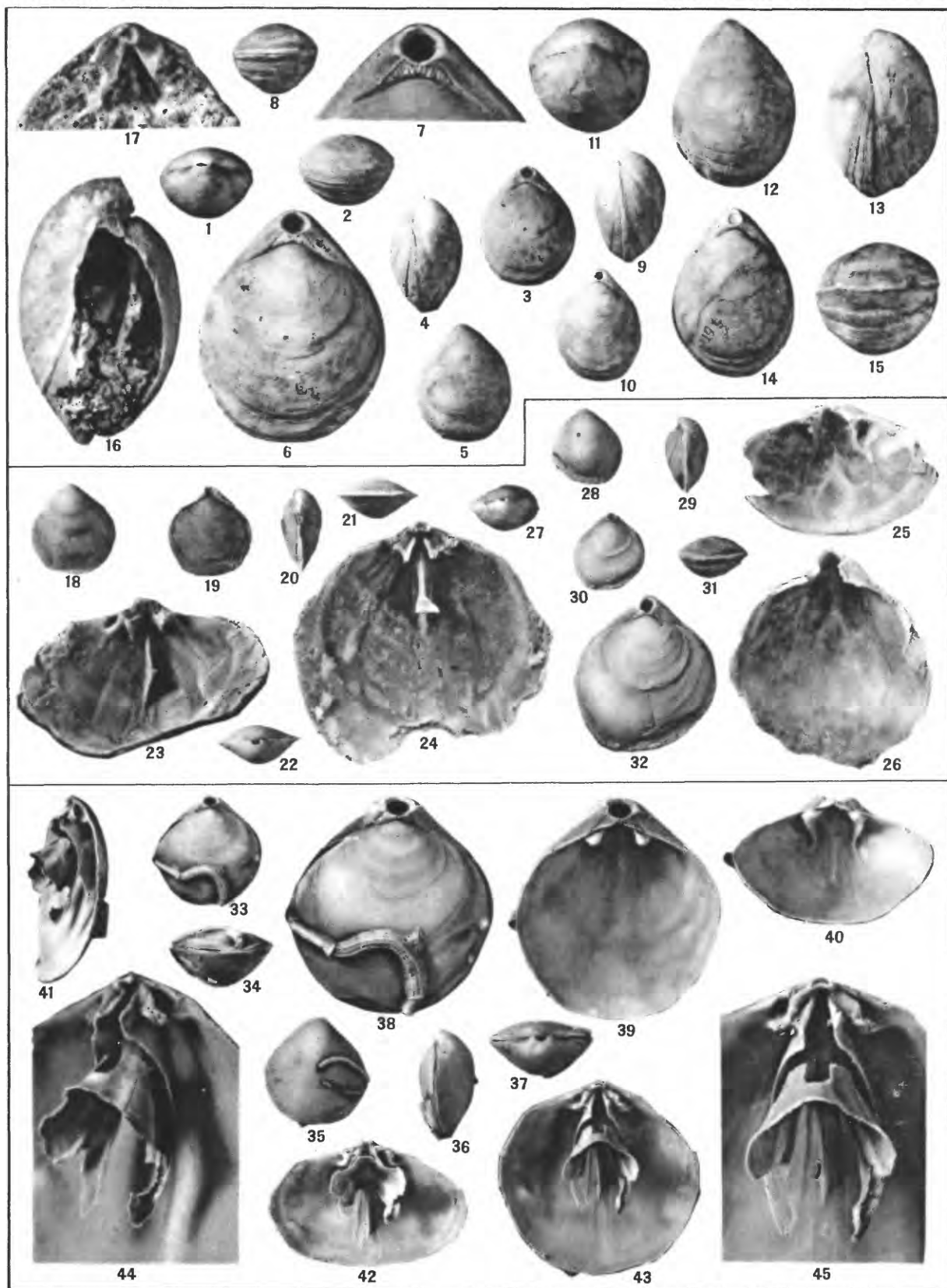


PLATE 4

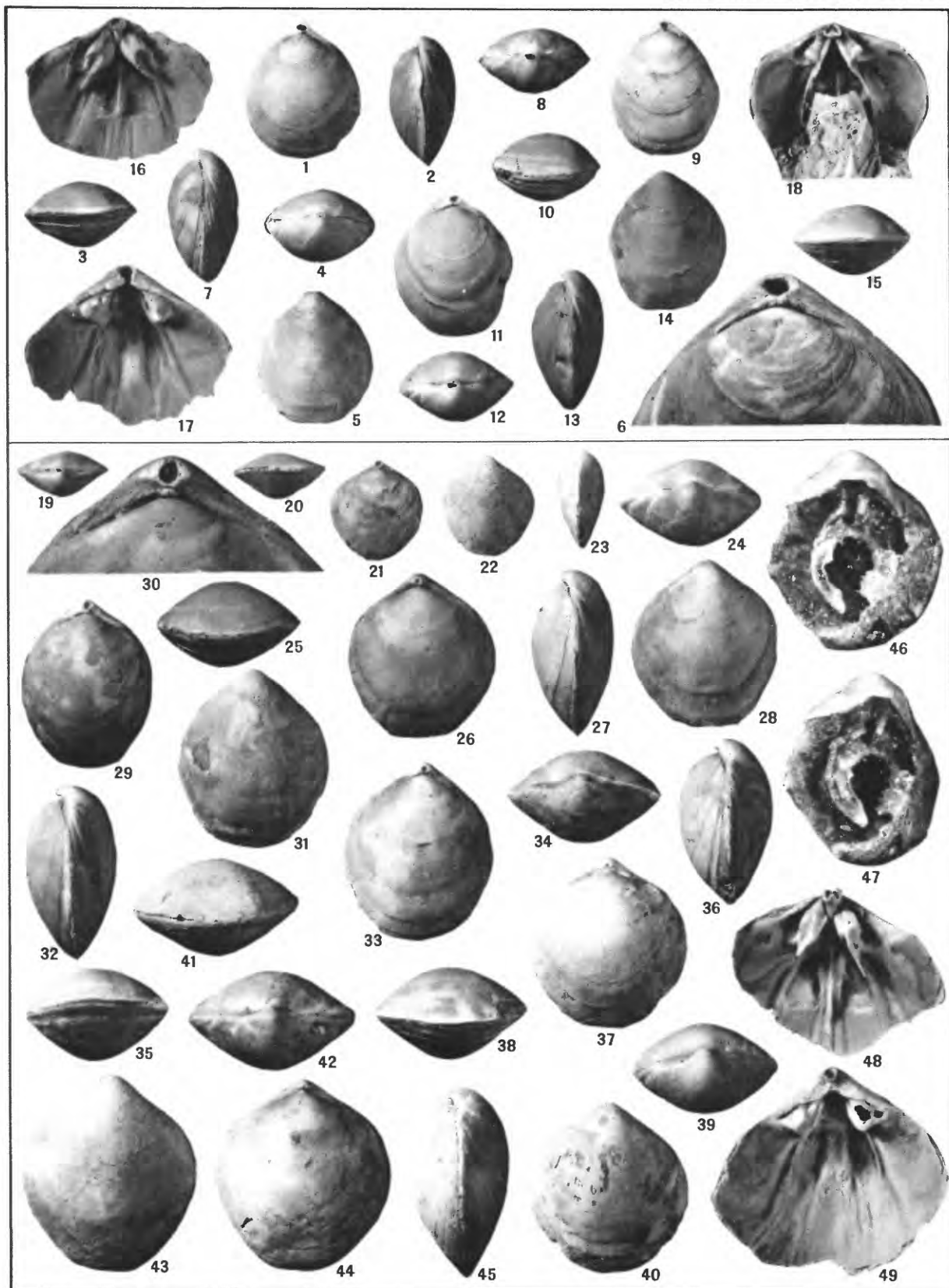
FIGURES 1-17. *Jolonica ryukyuensis* Yabe and Hatai. (p. 14).

- 1-5. Respectively posterior, anterior, brachial, side and pedicle views of a nearly perfect specimen, $\times 1$, hypotype USNM 549328.
6. Brachial view of the same specimen, $\times 2$.
7. Posterior of same specimen, $\times 3$, showing details of beak, circular foramen and symphytium.
Naha limestone, USGS 17624.
- 8-10. Respectively anterior, side and brachial views of a specimen smaller than the preceding, $\times 1$, hypotype USNM 549325.
Naha limestone USGS 17517.
- 11-15. Respectively posterior, pedicle, side, brachial and anterior views of an obese individual, $\times 1$, hypotype USNM 549327.
Naha limestone, USGS 17618.
16. Large specimen with side partially removed to show long loop and hood within, $\times 1\frac{1}{2}$, hypotype USNM 549326.
Naha limestone, USGS 17572.
17. Posterior part of a brachial valve prepared to show large cardinal process and hinge-plates, $\times 4$, hypotype USNM 549290.
Naha limestone USNM (Cooper) 901.
- 18-32. *Jolonica macneili* Cooper, n. sp. (p. 14).
- 18-22. Respectively pedicle, brachial side anterior and posterior views of a somewhat flattened specimen, $\times 1$, paratype USNM 549323a.
23. View of the interior of the brachial valve tilted to show median septum, crural bases and hinge-plates, $\times 3$, paratype USNM 549323c.
24. Another brachial valve in full view, $\times 4$, showing cardinal process and hinge-plates, holotype USNM 549323d.
- 25, 26. Two views of the interior of the pedicle valve of the holotype, counterpart to the preceding, $\times 3$, the first tilted to show the dental plates but the second in normal view to show the median ridge and elongate muscle scars.
Shinzato tuff, USGS 17633.
- 27-31. Respectively posterior, pedicle, side, brachial and anterior views of another complete specimen slightly crushed, $\times 1$, paratype USNM 549313a.
32. Same, $\times 2$, showing beak characters.
Chinen sand, USGS 17482.
- 33-45. *Jolonica hedleyi* Dall (p. 13).
- 33-37. Respectively brachial, anterior, pedicle, side and posterior views of the holotype, $\times 1$, USNM 111059.
38. Brachial exterior, $\times 2$, of the holotype.
- 39, 40. Interior of the pedicle valve of the holotype showing teeth, deltidial plates, and weak median ridge, figure 39 showing the valve tilted to reveal the strong dental plates, $\times 2$.
- 41-43. Brachial interior of the holotype, $\times 2$, showing the loop in three positions: respectively from the side, anterior and in full view.
- 44, 45. Side and full views of the loop of the holotype, $\times 4$, showing the broad transverse band with its deep, rectangular indentation.
Recent, U. S. Bur. Fisheries Station 5172, off Jolo, Philippine Islands, on sand at 318 fathoms.

PLATE 5

FIGURES 1-18. *Pictothyris picta* (Dillwyn) (p. 16)

- 1- 5. Respectively brachial, side, anterior, posterior and pedicle views of a well-preserved specimen, $\times 1$, hypotype USNM 549331.
6. Posterior of the preceding specimen, $\times 3$, showing foramen and symphytium.
Naha limestone, USGS 17521.
- 7-10. Respectively side, posterior, brachial and anterior views of a complete specimen, $\times 1$, hypotype USNM 549330b.
- 11-15. Respectively brachial, posterior, side, pedicle and anterior views of another complete specimen, $\times 1$, hypotype USNM 549330a.
- 16, 17. Posterior parts of the brachial and pedicle valve showing cardinalia, teeth and other details of the interior, $\times 2$, hypotype USNM 549330c.
Naha limestone, USGS 17498.
18. Interior of another brachial valve showing the loop with cardinal process and hinge plates, $\times 2$, hypotype USNM 549341a. Note broad, notched, transverse band.
Naha limestone, USGS 17522.
- 19-49. *Kikaithyris hanzawai* (Yabe) (p. 17)
- 19-23. Respectively posterior, anterior, brachial, pedicle and side views of a young specimen, $\times 1$, hypotype USNM 549302.
- 24-28. Respectively posterior, anterior, brachial, side and pedicle views of a wide adult showing small foramen, $\times 1$, hypotype USNM 549301.
Yontan limestone, USGS 17660.
29. Brachial view of a long slender specimen, $\times 1$, hypotype USNM 549289.
30. Posterior of the preceding specimen, $\times 3$, showing small foramen and thick symphytium.
- 31-35. Respectively pedicle, side, brachial, posterior and anterior views of a well-preserved specimen, $\times 1$, hypotype USNM 549297. Note minute foramen.
Naha limestone, USNM (Cooper) 901.
- 36-40. Respectively side, brachial, anterior, posterior and pedicle views of another complete specimen, $\times 1$, hypotype USNM 549299a.
Naha limestone, USGS 17517.
- 41-45. Respectively anterior, posterior, pedicle, brachial and side views of a large wide-shouldered specimen, $\times 1$, hypotype USNM 549298.
Naha limestone, USGS 17661.
- 46, 47. Two views of a specimen with the pedicle valve removed to show the loop, $\times 1\frac{1}{2}$, the second view turned to show the descending lamella, hypotype USNM 549304.
- 48, 49. Interior of posterior parts of a brachial and pedicle valve of the same specimen, $\times 2$, showing cardinal process, muscle and pallial marks, hypotype USNM 549300a.
Naha limestone, USGS 17630.



PICTOTHYRIS AND KIKATHYRIS