Contributions to the Geology and Palaeontology of Chiloe Island, Southern Chile

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CONTRIBUTIONS TO THE GEOLOGY AND PALAEONTOLOGY OF CHILOE ISLAND, SOUTHERN CHILE

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During the Royal Society Expedition to southern Chile in 1958 geological observations were made at Chepu and on the San Pedro tableland in the island of Chiloe. The island is composed of schist, Tertiary sediments, fluvioglacial deposits and volcanics. The schist, of uncertain age, forming the basement at Chiloe, is an extension of the schist of the coastal range of southern Chile, and falls in the chlorite zone (greenschist facies). It includes greenschists and altered gabbroic rock as well as normal quartzo-feldspathic schist, flat lying at San Pedro but strongly crumpled and folded on the west coast.

Tertiary or Quaternary volcanic rocks, of limited distribution, include banded rhyolite, partly spherulitic, and altered vesicular hypersthene andesite.

Upper Tertiary sandstone unconformably overlying the schist on the coast south of Chepu contains abundant fossil invertebrates (mainly Mollusca) attributed to the Lower Pliocene. The Chepu assemblage is intermediate in character and apparently in age between the Miocene (Navidad and Ranquil) faunas and the Middle Pliocene (Coquimbo) fauna of Northern and Central Chile, containing persistent Miocene elements together with Pliocene immigrant elements that do not occur together in the better known faunas of more northerly districts. Two new species of *Ocenebra* and a new subspecies of *Acanthina crassilabrum* Lamarck are described.

1. GENERAL INTRODUCTION

The first part of this paper summarizes the geological work carried out on Chiloe Island during the Royal Society expedition to southern Chile in the summer and autumn of 1958/59. The expedition spent 5 weeks (1 October to 5 November) at Chepu, a small farming colony on the west coast of the island, and 15 days (7 to 22 November) on the Cordillera San Pedro, an area typical of the higher country on the northern half of Chiloe Island (figure 1).

The Cordillera San Pedro, reached by a rough road from Piruquina, forms a more or less isolated schist plateau culminating in Cerro Capitan Maldonado (816 m). The plateau is separated from the Cerros de Metalqui to the west and the Cordillera de Piuchue on the south-west by a steeply incised stream, which rises on the western flanks of the Cordillera San Pedro and flows south and then east towards the low-lying country around Piruquina. From there it flows north as a main branch of the Rio Chepu and follows a gap in the coastal range to enter the sea at Chepu near the north-west corner of the island. For part of its course the river traverses thick fluvio-glacial beds, and detritus carried from these has been deposited as terraces near the mouth of the river and along the coast for some distance to the south.

Apart from peat and shallow alluvium the San Pedro area is a schist plateau the surface of which was probably originally continuous with that forming the Cordillera de Piuchue. The plateau arises gradually to several broadly rounded summits, and in the higher parts the topography is dominated by broad, gently sloping interfluves, with only shallow incision of the numerous small streams. Much of the higher part is open tussock grass country with scattered patches of forest. A conspicuous minor feature of the topography is the table-like nature of many of the schist outcrops; the flat-lying schistosity, combined with vertical jointing, gives low escarpment-like exposures along the sides of many of the small valleys. At the edge of the

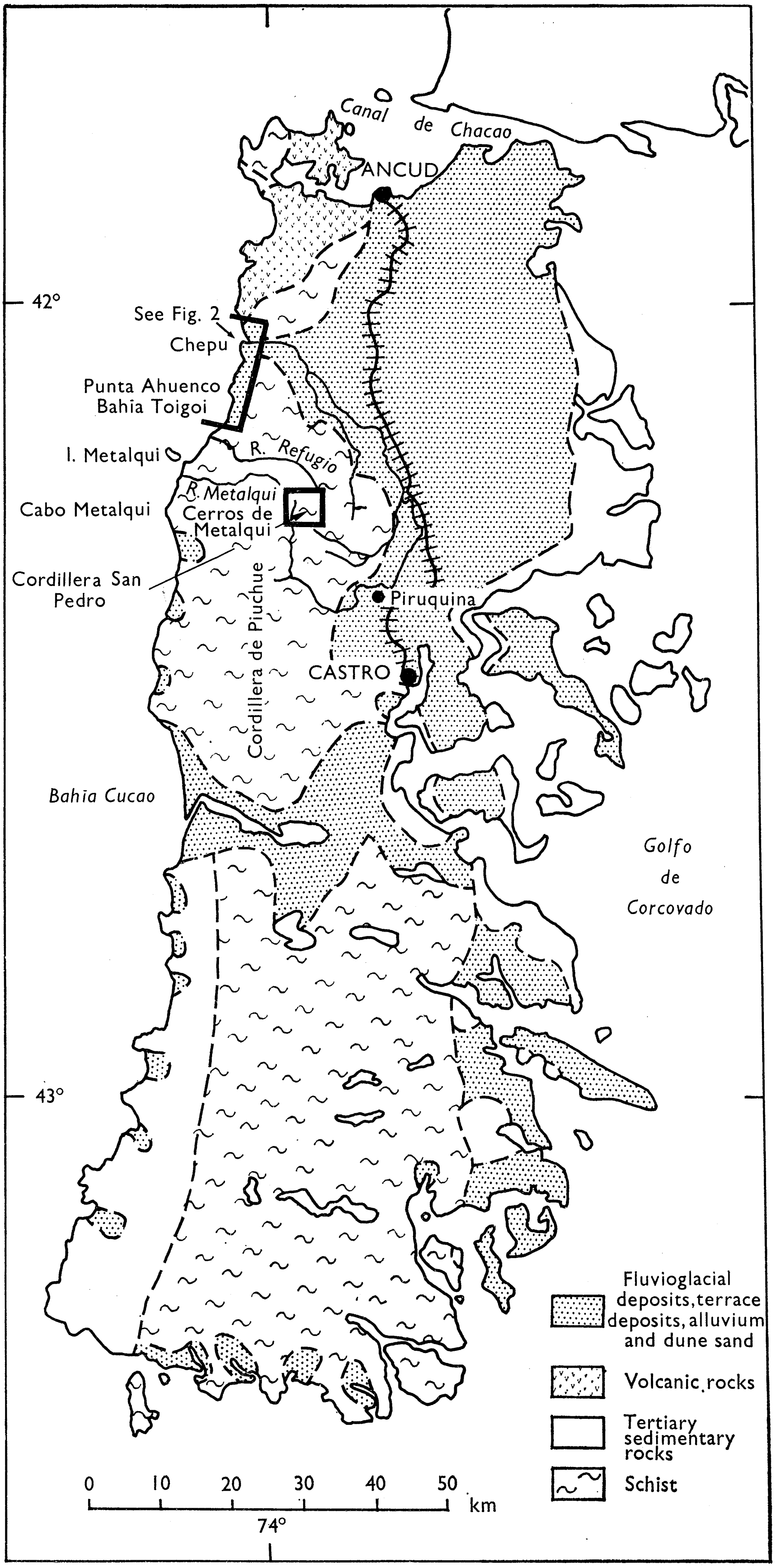

FIGURE 1. Geological sketch map of Chiloe Island, slightly modified from the 1:1000000 Geological Map of Chile (1960), showing the areas visited by the Royal Society Expedition, outlines in heavy black line.

highland on the east the streams become much more deeply incised, and the intervening ridges descend fairly abruptly in a series of broad steps towards the low-lying eastern part of the island. On the other side, part of the drainage from the Cordillera San Pedro flows west and north-west towards the sea as Rio Refugio and Rio Metalqui, which run for most of their courses in deep, densely forested valleys.

At Chepu the river is flanked on the north bank near its mouth by a wide area of wind-blown sand. To the north this is bordered by rugged forested country and, at the end of the beach, by high cliffs. Far to the south of the river the forest-clad western ridges of the Cordillera San Pedro and the Cerros de Metalqui fall steeply towards the coast. Between Rio Chepu and Rio Refugio, however, the hills slope much more gradually and merge with coastal terraces that have been partly cleared for grazing. The terraces are well defined up to 5 km from the coast, but farther inland their outline is blurred in many places by forest, so that their precise boundary with the coastal range is not clear.

The map (figure 2) and the description of the low-lying coastal features refer to conditions in late 1958, and we have been unable to obtain any definite information on the effects of the great earthquakes of May 1960 on the coast adjacent to Chepu. It is known, however, that a lowering of the land between 1 and 2 m relative to its former level took place along the Chilean coast between the Arauco Peninsula (lat. 37° S) and Chiloe Island (Watanabe & Karzulovic 1960; Ruiz & Saint-Amand 1961). Certainly, therefore, parts of the shore-line near Chepu, particularly at the mouth of the river and near the low lying-area at Punta Ahuenco, have been changed considerably as a result of the relative rise in sea level.

In the second part of the paper the Tertiary fossils collected by the expedition near Chepu are described and discussed. They are apparently intermediate in age between the faunas of the Navidad Formation (Lower to Mid-Miocene) and those of the Coquimbo Formation (Upper Pliocene) of north-central Chile. In north-central Chile, these formations, first recognized and named by Charles Darwin (1846), are separated by a gap in marine sedimentation during which differential earth movements led to elevation of the Andes and deposition of continental sediments in modern valley systems (Herm & Paskoff 1967; Herm 1969). On the Pacific coast of the island of Chiloe, however, part of the interval between the Navidad and Coquimbo formations appears to be represented by thin shallow-water marine deposits that are deposited on marine benches close to present sea level, cut by the sea in the pre-Tertiary schists that form the bulk of the island. The fossil invertebrates collected from these deposits include a mixture of elements restricted to either the Navidad or the Coquimbo beds of more northern parts of Chile and are here attributed to the Lower Pliocene, an age determination that should be tested by future studies, particularly if pelagic Foraminifera can be found.

Grateful thanks are expressed to the Royal Society of London and the Royal Society of New Zealand by the first author for the opportunity of visiting Chiloe Island and for financial support, and to the Council of the Department of Scientific and Industrial Research, Wellington, for leave to accompany the Royal Society Expedition to southern Chile. Dr R. K. Dell, Dominion Museum, Wellington, made available collections of Mollusca from Chile and a most useful manuscript catalogue of the Recent Mollusca of Chile. The second author is also indebted to Dr A. Myra Keen, Stanford University, California, and Dr Deitrich Herm, Bayerische Staatssammlung für Paläontologie und historische Geologie, Munich, for advice on systematic and biostratigraphic problems, and to Mr Norman Tebble, British Museum (Natural History), for assistance with literature not available in New Zealand. Professor M. F. Glaessner, University of Adelaide, South

Australia, kindly reported on the crab fragments, Professor W. A. Newman, Scripps Institution of Oceanography, University of California, on the fossil barnacles and Professor D. F. Squires, State University of New York, Stony Brook, Long Island, on the corals. We would like also to thank Dr H. R. Katz for his helpful comments on the text and for much advice and discussion of Chilean geography and geology, other members of the expedition for help in the field, and several local people for their hospitality, particularly the Muñoz family of Chepu and Sr and Sra M. Cifuentes, Piruquina near Castro.

PART I. GEOLOGICAL OBSERVATIONS ON CHILOE ISLAND IN 1958

By W. A. Watters

2. Outline of geology

Topographically and geologically Chiloe Island is an extension of the coastal range of southern Chile, and on the east is separated from the mainland by the Golfo de Corcovado, a submarine continuation of the great Central Valley of Chile. The island is made up of three main types of rock, namely schist, Tertiary beds, and fluvioglacial deposits. In addition, a small area of volcanic rock, probably upper Tertiary or Quaternary, is found at the north-west corner of the island. Figure 1, based on the 1:1 000 000 Geological Map of Chile (1960), shows the distribution of these formations, together with the outline of the areas covered during the expedition's visit. Not shown is a very small area of hornblende andesite of probable Tertiary age immediately west of Castro (Galli & Sanchez 1963*a*). This is possibly related to the mass of columnar trachyte 'behind Castro' mentioned by Darwin (1876, p. 391). Wright (1959, p. 34) and Besoain (1964) have shown that an important soil-forming material over the eastern part of Chiloe Island is volcanic ash derived from eruptions on the mainland.

At Cordillera San Pedro the entire area is made up of flat-lying schist with prominent north to north-west trending lineation. Greenschists and much-altered gabbroic rock were collected as boulders in one area. Schist also underlies the Chepu area, but there it is partially covered by a thin discontinuous strip of fossiliferous upper Tertiary sediments along the coast, by remnants of volcanic rocks (? Quaternary), and by Pleistocene to Recent terrace gravel and sand. Moreover, a very thick mass of banded rhyolite forms the cliffs and hills 2 to 3 km north of Rio Chepu; this is possibly correlative with the volcanic rocks exposed near Ancud (figure 1).

3. Schist

(*a*) *Previous work*

The occurrence of schist on Chiloe Island has been described briefly by Darwin (1876), Quensel (1912), Brüggen (1950) and Feruglio (1950). Darwin discussed the composition and attitude of phyllite and schist along the mainland coast north of the Taitao Peninsula (lat. 47° S) in considerable detail and referred more briefly to the schists on the south-east, west and north-west shores of Chiloe Island. He expressed the opinion that closely allied schists with nearly constant strike of schistosity are found '...from the southern part of Tres Montes [Taitao Peninsula] to the northern end of Chiloe, a distance of 300 miles...' (Darwin 1876, p. 457). Darwin also mentioned (p. 390) that granite and greenstone were said to exist in the central mountains of the island, but apart from small occurrences of altered basic rocks (see below) this has not been confirmed by later work.

During our field work we were impressed by the rounded form of the Cerros de Metalqui, as seen from both Chepu and Cordillera San Pedro, in contrast to the subdued plateau-like country of the Chiloe highlands visited by us. It seems possible that the summits of the Cerros de Metalqui are formed of rock different from the schist, but we were not able to confirm this.

Small bodies of serpentinite enclosed by the schist have been recorded from several localities in southern Chile north of Chiloe Island (Brüggen 1950, p. 9; Illies 1960).

(*b*) *Lithology and petrography*

Microscope examination shows that all the schists sectioned are almost completely recrystallized. Virtually no trace of original sedimentary textures is visible in thin section although bedding is still obvious in many outcrops. The rocks fall readily into the chlorite zone and belong to the greenschist facies.

Quartzo-feldspathic schists and, locally, greenschists are present. The most widespread schists contain quartz, albite (An_{3-4}), chlorite, muscovite, and accessory sphene, apatite, magnetite, hematite and, rarely, tourmaline. The relative proportions of some of the main minerals, however, vary considerably from place to place. In particular, quartz is very abundant in several of the rocks at San Pedro, a few of which contain only small amounts of albite. Many of the coastal schists between Rio Chepu and Punta Ahuenco are unusually dark and contain much fine-grained carbonaceous material, especially in the finer-grained layers. Similar 'graphitic' phyllite and schist were reported by Darwin (1876, p. 451) to be widespread along the coast north of the Taitao Peninsula. The schists appear to have been derived from interbedded quartz-rich sandstones and more argillaceous siltstones or mudstones, the former now being represented by quartz-rich schists and the latter by rocks with much muscovite and chlorite. Many of the schists are very similar in lithology to those of Otago, southern New Zealand. Mineralogically, however, they differ from these in the subordinate or, in some samples, the virtual absence of epidote (Hutton 1940), so that they were probably derived from sediments that were considerably more quartzose than the New Zealand rocks.

Greenschists were found at two localities, one at a small isolated mound of weathered rust-stained schist about ½ km north of the mouth of the Rio Chepu, the other near the end of the access road at San Pedro. In the second place, however, only loose pebbles were seen. The relationship of the greenschists to the surrounding much more abundant quartzo-feldspathic schists could not be observed at either locality. Typically the rocks contain albite, chlorite, epidote, subordinate actinolite and muscovite, and accessory apatite and sphene. Occasionally minor quartz is also present. The parent rocks were probably basic volcanics interbedded with the quartzo-feldspathic and argillaceous sediments. Their precise nature is more uncertain, but the presence of quartz in several specimens suggests that the greenschists may have been derived from impure tuffaceous beds rather than from flows or sills. In particular, the incoming of quartz and muscovite in two of the samples from San Pedro suggests the presence of variable amounts of normal sedimentary debris mixed with basic tuff (cf. Hutton 1940, p. 54).

A few small specimens of altered basic rock, probably gabbroic, were found loose near the end of the San Pedro road. None was seen in place, so that its relation to the surrounding schists is unknown. The original texture is largely obscured by the complete recrystallization of plagioclase and by the partial replacement of the original ferromagnesian minerals by a dense growth of fine-grained actinolite. The rock also contains scattered grains of pyrrhotite.

(*c*) *Attitude and structure*

On the Cordillera San Pedro the schistosity is either flat-lying or dips slightly towards the east. A prominent lineation, marked by fine-scale crumpling of the more micaceous layers of the schists, shows a constant trend between north and north-north-west over the area covered (about 25 km^2). The lineation plunges gently to the north in most outcrops.

On the west coast, south of Chepu, the schistosity is strongly crumpled in most outcrops, the structure in places approaching a coarse rodding. At several exposures (e.g. the north end of Bahia Goaibil beach, and the south end of Bahia Toigoi) surfaces perpendicular to the lineation show that the separate foliae are very sharply folded and that some are cut off completely by the more severe crumples, producing irregular boudin-like slices rather than continuous (though contorted) layers. In a few outcrops only, notably on Islote Ahuenco and north of Rio Chepu, the schistosity plane is well marked and strikes close to east–west and dips up to 55° to the north. Lineation, nearly everywhere trending NE–SW, with a plunge of up to 20° to the north-east, is well shown in most outcrops, particularly as crenulations or wrinklings of low amplitude (generally less than 2 mm) on the more micaceous layers of the schist. Normally the direction of lineation coincides with that of the larger crumples in the schist. Overturning of these crumples towards the west suggests that pressure, probably post-metamorphic, was from the east or south-east.

(*d*) *Discussion*

No local evidence of the age of the schist is found either at Chepu or on the Cordillera San Pedro. Various writers (e.g. Feruglio 1950; Muñoz Christi 1956; Illies 1960) consider a Precambrian age for the schists of southern Chile to be the most likely, although they do not rule out the possibility that some are Palaeozoic or even Mesozoic (cf. Fuenzalida 1957, p. 269). Recently Gonzales-Bonorino (1967) published an age determination of 210 million years for quartzose schist from Pichilemu, 150 km south of Valparaiso, part of the crystalline basement of the coastal cordillera. The date obtained, representing the age of metamorphism, is Triassic, although Gonzales-Bonorino (1967, p. 4) suggests that this is possibly a minimum age and that the true time of metamorphism is late Permian. He regards the age of the sediments themselves as probably not older than Middle Palaeozoic.

The schist of Chiloe Island can be regarded as an extension of that widely exposed in the coastal range of southern Chile. On the 1:1 000 000 Geological Map of Chile (1960), schist of this region (including Chiloe Island) is designated PC (undifferentiated Precambrian Metamorphic Rocks), whereas the schists farther south, namely those making up most of the Chonos Islands (lat. 44°–45° 30′ S) and part of the Taitao Peninsula (47° S), are shown on the map as distinct, namely PP (Palaeozoic and/or Precambrian Metamorphic Rocks). It is clear, however, from Darwin's description (1876, p. 451) that some of the schists on the Chonos Islands are similar to the carbonaceous schist found south of Chepu. Darwin (1876, p. 456) stressed the resemblance of the Chiloe Island schist to that of the Chonos Islands, although he noted that '...on the west and north-western shores [of Chiloe Island] the foliation was often obscure' (p. 456), an observation confirmed for the Chepu area by the present work. On the other hand, there is some evidence that the Chiloe Island schist differs somewhat from that farther north, at least in the Valdivia district (lat. 39° 45′ S), some 250 km north of Chepu. Here Darwin had noted that the schist was in places more ferruginous and feldspathic than that of the Chonos Islands. Illies (1960) has described in detail the Valdivia schist, named by him the Piedra Laja Formation. He distinguished two main types, which grade into one another by passage rocks. The first type, of lower grade, shows macroscopically recognizable sedimentary features such as bedding and grading, while the second comprises higher-grade rocks in which the fabric has been wholly determined by metamorphism. The rocks examined by me on Chiloe Island appear to resemble more the higher-grade schist of the Valdivia region described by Illies, although rocks carrying garnet and kyanite, observed by Illies (1960, p. 38), were not recorded at Chepu or San Pedro.

In summary, the Chiloe schist examined is, on the evidence available, closer in lithology to that of the Chonos Islands and Taitao Peninsula than to the metamorphic rocks of the Valdivia region. Its age remains in doubt.

4. Tertiary sedimentary rocks

(*a*) *Distribution and thickness*

Along the coast south of Chepu several small areas of upper Tertiary sandstone rest directly upon the eroded and, in places, uneven surface of the schist (figure 2), particularly at Punta Pulga and around Punta Ahuenco (figures 3 and 4, plate 26). Far to the south, on the steep coastal slopes immediately east of Isla Metalqui, light-coloured rocks, which appeared from the distance to be horizontally layered, could possibly be Tertiary beds.

The Tertiary sediments between Chepu and Bahia Lar are nowhere more than 30 m thick. The underlying schist surface is of considerable relief in places, for at Punta Ahuenco small steep-sided stacks of sandstone are found within only a very short distance of the large schist exposure forming Islote Ahuenco (figure 2). The dip is generally up to 12° almost due west, and as the schist is exposed in many places at the base of the cliffs the Tertiary beds must thin out only a short distance inland. The landward boundary between the schist and the Tertiary is, however, covered by gravels and was not observed.

(*b*) *Content*

The sandstone is compact and is composed mainly of quartz, partly weathered feldspar, and tiny grains of weathered volcanic rock. A few thin pebble bands are present, and here and there, as at Punta Pulga, small irregular calcareous concretions are present. A thin section of one of these (38756) shows grains of quartz, acid plagioclase, augite and brown hornblende, as well as numerous tiny rock fragments, set in a calcareous cement. The rock fragments include schist and fine-grained volcanic rock with texture similar to that of many andesites.

On the wide wave-cut platform which existed just north of Punta Ahuenco at the time of our visit large septarian concretions of very hard arenaceous rock rich in iron oxide were seen to stand out from the surrounding softer sandstone. Thin irregular vein-like masses of lignitic coal and portions of tree trunks at two localities suggest that the beds were probably laid down in very shallow water, possibly estuarine in some places.

Excellently preserved marine fossils collected at several localities (see figure 2) are described in Part II. They are attributed tentatively to the Lower Pliocene.

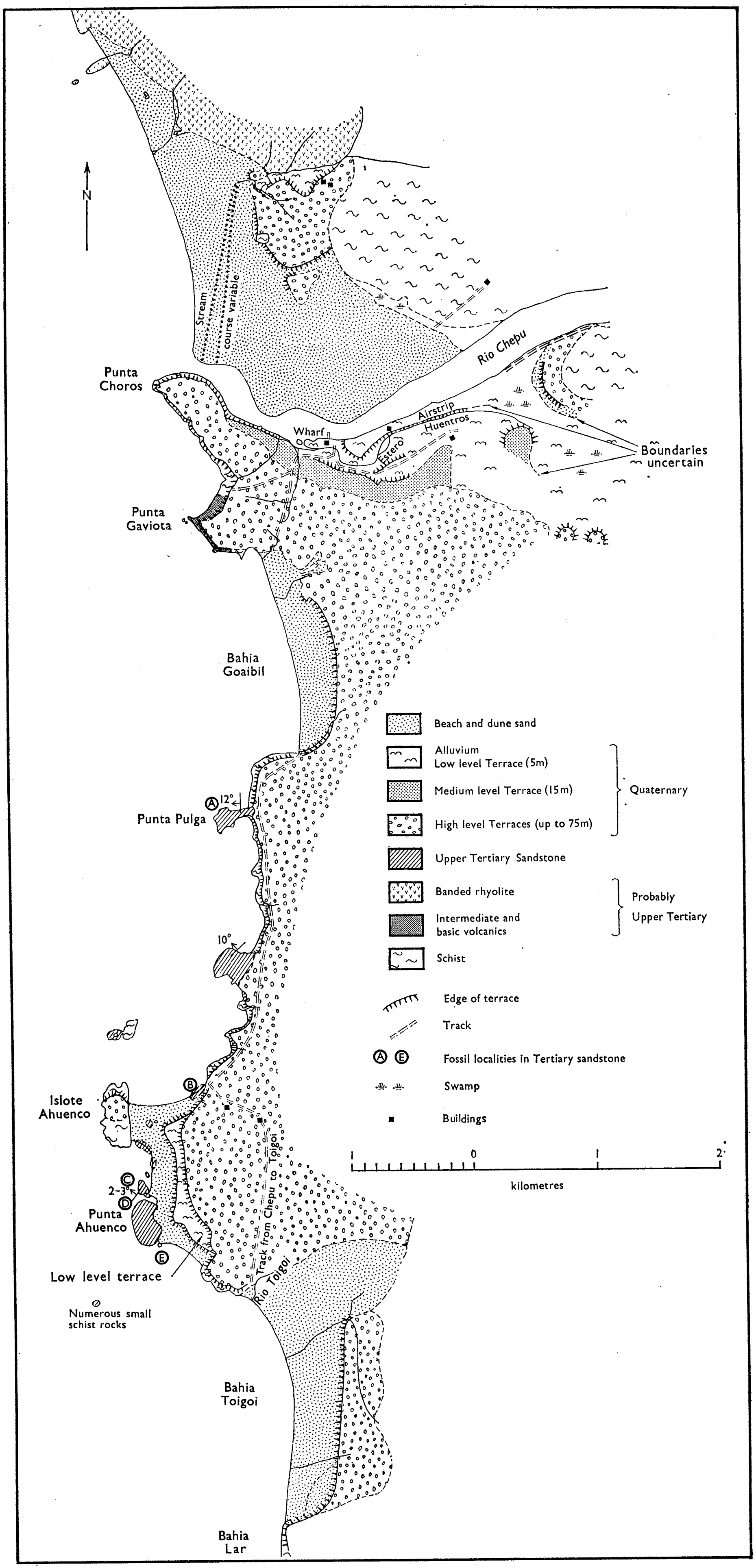

Figure 2. Geological sketch map of the coastal area near Chepu, west side of Chiloe Island, based on a plane-table survey by W. A. Watters.

Discontinuous coastal exposures of Tertiary sediments are known immediately north of the Canal de Chacao and, more continuously, along the east side of the coastal range north-west of Puerto Montt (Katz 1963); moreover, Tertiary sediments are widespread on the southern part of Chiloe Island. While it is probable that beds of the same age as those described from near Chepu are found elsewhere in Chiloe and Llanquihue provinces on the Chilean mainland, the fossils previously recorded from near Ancud, Castro and Bahia Cucao suggest that Miocene is also represented (see Part II).

5. Volcanic rocks

Massive volcanic rocks crop out in two areas, namely (i) 2 to 3 km north of the mouth of Rio Chepu, and (ii) around Punta Gaviota, about 400 m south of the river mouth.

(*a*) *Distribution*

(i) *North of Rio Chepu*

The rock forming the steep cliffs and sharply pinnacled islets 2 km north of the river mouth is a banded rhyolite. This rock makes up much of the coastal hills commencing about 1.5 km north of the Rio Chepu and is possibly contiguous with the volcanic rocks long known from the Ancud district (Darwin 1876, pp. 391–397; see also Galli & Sanchez 1963*b*). In addition, several outcrops of a dark, vesicular, rather altered andesitic rock, too small to be shown on figure 2, are present north of Rio Chepu a little above high tide mark. Their relations with the nearby rhyolite were, however, hidden by beach sands at the time of our visit.

(ii) *Punta Gaviota*

Dark andesitic rock is exposed along the coast for about 800 m and is particularly well seen in several large stacks showing a coarse columnar jointing. The andesite overlies the schist directly and appears to form a flat-lying sheet up to 15 m thick. No exposures were seen inland because of the cover of gravels.

(*b*) *Description*

North of Rio Chepu the rocks are partly altered hypersthene andesites, which are vesicular in places and are accompanied by considerable amounts of secondary opal, chalcedony (including banded agate), and sideritic carbonate. The overlying rhyolite is non-porphyritic, partly spherulitic, light-coloured, poor in ferromagnesian minerals and generally finely banded. The general attitude of the rocks is probably horizontal but this is obscured by the very pronounced contortion of the banding.

At Punta Gaviota the rock is hypersthene andesite, coarser-grained than that north of the river mouth but generally similar to it in mineralogical composition and in places similarly altered.

Petrographic and chemical data on the volcanic rocks will be published separately.

(*c*) *Discussion*

No field evidence is available to indicate the age of the volcanic rocks other than that they rest directly on the schist south of the mouth of Rio Chepu. It seems reasonable to correlate them with the volcanics of the Ancud district, 20 to 25 km to the north-east (Darwin 1876, pp. 391–397; Galli & Sanchez 1963*b*). The volcanics are depicted on the 1:1000000 Geological Map of Chile (1960) as reaching the west coast of Chiloe somewhat north of Rio Chepu and separated from it by a thin strip of schist. From the present work, however, the volcanics are now known to come to within 2 km of the mouth of the river. They are shown on the map as Quaternary or Tertiary. Galli & Sanchez (1963*b*) stated that their true age is unknown, but '...for lack of other arguments, lean toward an age of Tertiary–Quaternary' (p. 1274). They list andesite, welded tuff and volcanic agglomerate as the rock types present in the immediate environs of Ancud.

6. Pleistocene to Recent terrace deposits

Much of the comparatively low-lying coastal area from the north of Rio Chepu to Bahia Lar is underlain by fluvial gravel and sand of variable thickness. These extend for some distance inland in the terrace behind Bahia Toigoi, while at Chepu the terrace deposits can be traced inland along the comparatively low country of the Chepu valley where they merge with the fluvio-glacial deposits that are widespread on the eastern part of Chiloe Island (figure 1).

Several distinct terrace levels could be recognized, and at many places along the coast the difference in level between the foot and the top of terraces was measured by aneroid barometer. However, the heights given below are approximate only, because the higher terraces are dissected and bear a widespread cover of forest and scrub.

75 *metres*. Comparatively small areas that may form the remnants of a distinct terrace at about 75 m are present at Chepu, e.g. on the forest-clad hill east of the Chepu airstrip, as well as mesa-like remnants in the upper part of Estero Huentros (figure 2). As far as could be observed, these remnants, when traced westwards, merge with a somewhat dissected surface sloping very gently towards the top of the coastal cliffs, the height of which is generally between 30 and 40 m above sea level. Despite its dissection, this surface forms a marked coastal bench, rising very gradually inland, and is particularly noticeable when observed from a distance or from the air.

20 *to* 27 *metres*. This terrace is well exposed behind the wide sand flat on the north side of Rio Chepu, and behind Bahia Toigoi and Bahia Goaibil, and in many places its edges show excellent exposures of gravel and current-bedded sand. At Chepu and Toigoi the terraces are marked by a prominent upper layer of dark red-brown sandstone, possibly an iron pan in an old soil profile, in many places strongly cemented. At Chepu this forms a lip in places at the edge of the terrace and stands a few feet above the general surface.

15 *metres*. This is a prominent, though narrow, terrace following the south side of Rio Chepu, but it becomes indistinct when followed inland beyond three km.

5 *metres*. This terrace is visible in two localities only, namely near Islote Ahuenco, where it forms a rather hummocky bench behind the beach, and along both sides of Estero Huentros. The Chepu airstrip lies on the northern part of this terrace.

Thin layers rich in marine shells, all similar as far as I could judge to present-day forms on the local beaches, were seen at several places near Chepu. They occur at three distinct levels, namely at about 1.6 m, 5 m, and between 14 and 15 m above mean sea level.

Correlation of the terraces has not been attempted, not only because of the absence of data from adjoining districts but also because active and appreciable tectonic movements are still in evidence along the coastal region (cf. Darwin 1876, pp. 233–234, 236). Tentatively, however, the 30 to 40 m and 20 to 27 m terraces may possibly be related to the last interglacial Cancagua terrace described by Illies (1960, pp. 57–59) from the neighbourhood of Valdivia (39° 50′ S).

PART II. PLIOCENE MARINE INVERTEBRATES FROM CHEPU DISTRICT, CHILOE

By C. A. Fleming

7. Fossil localities

The collections were obtained from five localities (shown on figure 2) near Chepu, as follows:

A. Punta Pulga: north-west point of peninsula of Tertiary rocks, dipping westward at 12°.
B. Beach platform, 500 m east of north end of Islote Ahuenco.
C. Sandstone stack, *ca.* 300 m south of south end of Islote Ahuenco.
D. Sandstone platform, 500 to 550 m south-south-east of south end of Islote Ahuenco.
E. Isolated stack, south-east side of Punta Ahuenco.

The material consists of some hundreds of specimens, mainly Mollusca and Cirripedia, with a few corals, polyzoa, polychaete tubes and crab claws, in a fair state of preservation, in fine to coarse sandstone, locally containing quartz pebbles. Most of the sandstone matrix can be removed with a needle, but on some specimens it is concretionary. Collection E contains about 17 taxa, and the other collections, with fewer species, resemble it in having several forms in common. The most abundant specimens are *Acanthina crassilabrum katzi* subsp.nov., which are present in all collections. The collections are held at the New Zealand Geological Survey and are referred to in this paper by that institution's catalogue numbers (World Mollusca collection, prefix WM; Primary types, prefix TM; Corals, prefix CO).

8. Previous work on Cenozoic fossils from Chiloe

When Darwin (1846) reported the presence of Tertiary sandstone and laminated mudstone 'for twenty miles north and south of Castro', he recorded from concretions in one locality poorly preserved marine Mollusca that were described by Sowerby (in Darwin 1846) as four species. Although Darwin named and distinguished the Navidad and Coquimbo beds, he suspected that the fossils collected from different localities all belonged to nearly the same epoch, and thought them nearly contemporaneous with the Eocene.

In his monograph, *Die Tertiären und Quatären Versteinerungen Chiles*, R. A. Philippi (1887) summarized the occurrences of Tertiary fossils on Chiloe known to him, including those recorded by d'Orbigny (1842), Darwin (1846), and Hupé (1854). He mentioned (p. 18) collections from the Bay of Ancud, especially from Ranquil and Huinimo, and from a locality on the west coast near Cucao, where his son collected at a cave (Cueva de Cucao), and repeated Darwin's description of the beds near Castro. On pp. 250–251 of his monograph, Philippi listed the 46 species of Tertiary invertebrate fossils known to him from Chiloe and the Guaitecas Islands. In the systematic part of the volume, 15 species are recorded from Ancud, seven species from Cucao, one from near Quetralmahue, and 19 species from unspecified localities in Chiloe, including the four taxa named by Sowerby. Philippi classed all the Chilean Tertiary faunas known to him as Eocene (p. 254), but recognized the considerable differences between the Coquimbo fauna of northern Chile and the Navidad and other faunas of southern Chile, including those from Chiloe.

In 1896 W. Möricke collaborated with G. Steinmann in an account of the Tertiary deposits of northern Chile, in which they emphasized the distinction between the faunas grouped in

Figure 3. Coast near Punta Pulga, Chepu District, looking south, showing gently dipping Pliocene sandstone. Schist forms the base of the cliffs in the foreground. The rounded summits in the distance are the Metalqui Hills. (Photo by W. A. Watters.)

Figure 4. Coast at Punta Ahuenco, Chepu, looking north, showing stacks developed in Pliocene fossiliferous sandstone. (Photo by G. A. Knox.)

FIGURE 5. Pliocene Bivalvia from Chepu, Chiloe Island. (*a*) *Crassostrea* sp. (WM 10599a). (*b*) *Epilucina* cf. *promaucana* (Philippi) (WM 10601). (*c*) *Choromytilus* cf. *chorus* (Molina) (WM 10597). (*d* to *f*) *Dosinia* aff. *semilaevis* (Philippi) (WM 10603, 10602). (*g*) *Mulinia* sp. (WM 10605a). (*h*, *l*) *Solen* aff. *crucis* Ihering (WM 10608a, 9496a). (*i*) *Amiantis* (*Eucallista*) aff. *domeykoana* (Philippi) (WM 9495a). (*j*, *k*) *Panopea* aff. *ibari* Philippi (WM 9497). Figures × 1, except (*g*), × 2.5.

FIGURE 6. Pliocene Gastropoda from Chepu, Chiloe Island. (*a*) *Patinigera* aff. *terroris* (Filhol) (WM 10612). (*b*, *c*) *Tegula* (*Agathistoma*) aff. *patagonica* (d'Orbigny) (WM 10613). (*d* to *g*) *Polinices* (*Neverita*) sp.nov. ?aff. *secunda* (Rochebrune & Mabille) (WM 9498, 10619a). (*h* to *j*) *Ocenebra* (*Crassilabrum*) *wattersi* sp.nov., holotype (TM 4845). (*k*, *v*) *Lamprodomina dimidiata* (Sowerby) (WM 9730a, b). (*l*) *Ocenebra kuscheli* sp.nov., holotype (TM 4844); (*m* to *s*) *Acanthina crassilabrum katzi* subsp.nov. holotype (TM 4856), (*n*, *p*, *s*) and paratypes (TM 4857, 4858). (*t*, *w*) *Olivancillaria* (*Lintricula*) *tumorifera* (Hupé) (WM 10629). (*u*) *Chorus* aff. *blainvillei* (d'Orbigny) (WM 10628). Figures × 1.25, except *l*, × 2.5.

the Navidad Stufe, attributed to the Miocene to Uppermost Oligocene, and those grouped as the Coquimbo Stufe, attributed to the Upper Miocene or Pliocene. Möricke (1896) had only two species from the island of Chiloe, and he grouped the Chiloe Tertiary collections listed by Philippi with those of the Navidad Stage that are widespread in southern Chile rather than with the Coquimbo Stage. He pointed out, however, that both stages seemed to be represented at certain places in southern Chile (Tubal, Cahuil, etc.).

More recent studies of the Chilean Tertiary, in part summarized by Hoffstetter, Fuenzalida & Cecioni (1957, pp. 239–246), have confirmed Möricke's views on the age difference between the Navidad and Coquimbo stages as typically developed and have led to the introduction of additional stages. Brüggen (1934) separated the Paleocene and Eocene part of the original Navidad Stage as the Concepcion Stage, and Tavera (1942), working in Arauco Province, divided the Navidad (in Brüggen's sense) into two, further restricting the Navidad to the lower part (attributed to Lower Miocene) and proposing a Ranquil Stage for the Upper (attributed to Upper Miocene). A different correlation was made by Groeber (quoted by Hoffstetter *et al.*) who considered the Navidad to be Oligocene and the Ranquil to be Lower Miocene. The upper part of the Navidad beds at their type locality has been correlated with the Tortonian (Upper mid-Miocene) by Martinez & Osorio (1964) from studies of Foraminifera and discoasterids. Herm & Paskoff (1967) emphasized that a time interval separates the Coquimbo Formation from the Navidad in central-north Chile, attributed the former to the Upper Pliocene and the latter to the Upper Miocene, and confirmed Möricke's conclusions on the contrast between the macrofossils of the two formations.

In his more detailed account of the sequence of molluscan faunas in North and Central Chile (1969), Herm reported a Lower Miocene (Aquitanian) assemblage of pelagic Foraminifera from near the base of the type Navidad Formation, but considered that its upper members probably extended into the Middle or even Upper Miocene. Herm considered the lowest Coquimbo faunas to be Middle Pliocene and confirmed their distinction from the Miocene Navidad faunas by analysis of their contrasting characteristics, so that he concluded a major faunal reconstruction took place near the Miocene–Pliocene boundary. Herm considered the fauna of La Cueva to be younger than the Coquimbo faunas and classed it as Upper Pliocene. Herm's review of Coquimbo Mollusca, the first comprehensive revision of Philippi's work (1887), has proved extremely useful for the evaluation of the collections from Chiloe described in this paper.

9. SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA

Class ANTHOZOA

Order SCLERACTINIA

Family OCULINIDAE

Genus *OCULINA* Lamarck

Oculina remondi Philippi

Oculina Remondi Philippi, 1887, p. 233, pl. LIII, fig. 3.

Oculina Remondi Philippi, Möricke, 1896, p. 589, pl. XII, figs 6, 7.

Several fragments (CO 1410–1413) of irregular branching coralla, less regularly cylindrical than those illustrated by Philippi and Möricke, were obtained from Locality E.

O. remondi was described from Caldera and thought by Möricke (1896) to be restricted to the Coquimbo Stage. Herm (1969, p. 89) lists it as a characteristic form that first colonized the area in the Pliocene.

Phylum MOLLUSCA

Class BIVALVIA

Order MYTILOIDEA

Family Mytilidae

Genus *CHOROMYTILUS* Soot-Ryen 1952

Type species: *Mytilus chorus* Molina 1782.

Choromytilus cf. ***chorus*** (Molina), figure 5*c*, plate 27.

Mytilus chorus Molina, 1782, *Saggio sulla Storia Naturale del Chili*, p. 202.

Choromytilus chorus (Molina); Soot-Ryen, 1955, p. 31, pl. 2, figs, 7, 8 (*cum synon.*).

A right valve (WM 10597) and fragments of another from Locality E. The generic position is confirmed by what can be seen of the musculature. Although probably conspecific with the Recent Chilean species, the fossils differ somewhat in outline from Recent specimens and from Soot-Ryen's figures. *Choromytilus chorus* was found in the Coquimbo Stage by Möricke (1896, p. 550) and from Isla del Rei and from Angochilla by Philippi (1887), but is not recorded from the type Navidad fauna, being one of the 'Pacific' elements forming the majority of the genera that first colonized the Chilean coast in the Pliocene. In younger Pliocene beds *Choromytilus chorus* is represented by giant individuals (Herm 1969, p. 90).

Genus *MODIOLUS* Lamarck 1799

Modiolus cf. ***eiseni*** Strong & Hertlein, figure 7*a*.

Modiolus eiseni Strong & Hertlein 1937, *Prof. Calif. Acad. Sci.* **22**, 160–161, pl. 34, figs. 11, 14–16.

A broken left valve, 11 mm long, from Locality B (WM 9493) agrees most closely with *M. eiseni* among the living West American species of *Modiolus* (Soot-Ryen 1955) and cannot be more closely matched among the six Tertiary species from Chile described by Philippi (1887). *Modiolus* is not recorded in the Pliocene (Herm 1969).

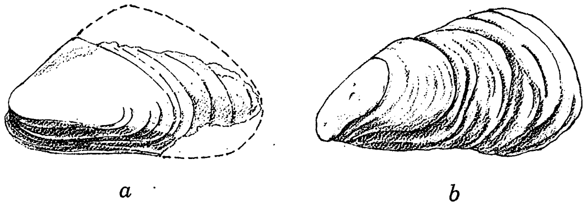

Figure 7. *a*, *Modiolus* cf. *eiseni* Strong & Hertlein (WM 9493). *b*, ? *Xenostrobus* sp. (WM 9494). Chepu, Chiloe Island. Approximately × 3.

Genus *XENOSTROBUS* Wilson 1967

Type species (by original designation): *Volsella inconstans* Dunker 1856. Recent, Southern Australia.

Xenostrobus was differentiated from *Modiolus* mainly from anatomical characters (Wilson 1967) and includes three species in Australia and New Zealand, probably a fossil species (Pliocene–Pleistocene) from New Zealand, and possibly a Japanese living species.

? **Xenostrobus** sp., figure 7*b*.

A left valve, 12 mm long, from Locality C (WM 9494), has an irregular growth form such as is common among gregarious intertidal specimens of *Xenostrobus pulex* (Lamarck), a widespread species of the rocky shores of Australia and New Zealand. In proposing the genus *Xenostrobus* Wilson (1967) noted the strong superficial resemblance of *X. pulex* to the Japanese *Mytilus atratus* Liske, suggesting possible close relationship which, if confirmed by anatomical studies, would strengthen the possibility that *Xenostrobus* has sufficient vagility in the larval stages to be dispersed from Australasia to Chile. Identification of a fossil *Xenostrobus*, however, must always remain uncertain. None of Philippi's figures of *Modiolus* resembles the Chepu specimen closely enough to suggest specific identity.

Order PTERIOIDA

Family Anomiidae

Genus *ANOMIA* Linnaeus

Anomia sp. ? cf. **crepiduliformis** Philippi

Of two worn valves from Locality E, one resembles Philippi's crude figure of *A. crepiduliformis* (1887, pl. 47, fig. 8) and both lack the radial ornament of *A. alternans* Sowerby and *A. atacamiensis* Herm, two species of Panamic affinity from the mid Pliocene (Coquimbo beds). Internally one specimen shows the musculature and lithodesma of *Anomia* s.str. The Coquimbo species are probably not closely related and certainly not descendants of the Chepu form.

Herm (1969, p. 93) stated that *Anomia* is absent from the Miocene but the type of *A. crepiduliformis* was from Navidad. *Anomia* no longer lives on the Chilean coast but *A. peruviana* d'Orbigny ranges south to Paita, Peru (Keen 1958).

Family Ostreidae

Genus *CRASSOSTREA* Sacco 1897

Crassostrea sp., figure 5*a*, plate 27.

Two left valves from Locality E and a fragment from A, with a maximum height of 57 mm. Growth uneven, in coarse irregular folds. No radial ornament or marginal denticulation. Ligamental area relatively large, rising high above the hinge line. Adductor muscle scar large, callous, somewhat impressed.

Many nominal species of '*Ostrea*' have been described from the Tertiary of western South America, but the number of valid taxa will certainly prove to be less. The Chepu specimens are poorly preserved. They do not closely resemble any of the specimens figured by Philippi (1887), Möricke (1896), or Herm (1969), but the specimen here illustrated (figure 5*a*), apart from its much smaller size, closely resembles the Pliocene species of *Crassostrea* from Chile (*maxima* Hupé 1854, not of Linnaeus 1758) and New Zealand (*ingens* Zittel) and the fossils from Patagonia figured by Ortmann (1902) under the name *Ostrea ingens* Zittel. During the Miocene, oysters were rare, small, and secondary elements in Chilean marine communities (Herm 1969) p. 93). They developed greatly, produced giant forms in the Middle Pliocene, and were reduced to a single species in the Pleistocene. One Recent species has been described from Chile (*O. chilensis* Philippi).

Order VENEROIDA

Family Lucinidae

Genus *EPILUCINA* Dall 1901

Type species (by original designation): *Lucina californica* Conrad. Pleistocene-Recent, California.

Epilucina* cf. *promaucana (Philippi) figure 5*b*, plate 27.

Lucina promaucana Philippi 1887, p. 181, pl. XXIV, fig. 6.

Phacoides promaucana (Philippi); Ihering 1907, p. 288.

An incomplete double-valved specimen from Locality C (WM 10601), showing the hinge of the left valve. The shell is *Dosinia*-like; ventral margin smooth, dorsal areas not differentiated; sculpture of rather crowded concentric threads, 3 per mm on centre of disk. Height 23.5 mm, inflation 8.5 mm.

The specimen agrees well with Philippi's figure and differs from *Phacoides promaucana crucialus* Ihering (1907; see also Ortmann 1902, pl. 27, figure 4) in its less evenly spaced concentric threads. It appears to be well placed in the genus *Epilucina* Dall, but in shape and sculpture resembles *E. concentrica* (Lamarck) from the Paris Basin Eocene more closely than the living type species *E. californica* (Dall), having a much less strongly projecting right valve lunule. Despite the external similarity of the Chepu fossil to *Callucina radiata* (Conrad) (Caribbean), the smooth ventral margin and apparent absence of dorsal areas prevent its classification in *Callucina*. It does not resemble the species of *Lucinoma* that are now the dominant type of lucinid living off the coast of Chile.

E. promaucana is recorded from the Navidad and Ranquil formations (Hoffstetter *et al.* 1957) and from the Suprapatagonian of Argentina (Ortmann 1902), but it is not known from the Coquimbo beds. A subspecies, *E. promaucana crucialis* (Ihering) was described from the Patagonian Miocene of Argentina.

Genus *DOSINIA* Grey 1835

Subgenus *DOSINIA* s.str.

Type species (by subsequent designation): *Dosinia concentrica* Born. Recent, West Indies and southeastern United States.

Dosinia* (*Dosinia*) aff. *semilaevis (Philippi), figure 5*d–f*.

Artemis semilaevis Philippi, 1887, p. 113, pl. 13, fig. 22.

Two specimens from Locality A and C, approximately 60 mm in height, are characterized by higher beaks and a narrower beak angle than most *Dosinia*. The lunule is diffuse, not deeply impressed or pouting, with a weak bounding groove. Hinge teeth are rather widely spread, less concentrated than in most Dosiniinae. In these characters the Chepu fossils agree quite closely with North American and Peruvian fossil species formerly grouped in the subgenus *Dosinidia* Dall but now placed in *Dosinia* s.str., such as *D. acetabulum* (Conrad) from the Miocene of Maryland and *D. delicatissima* Brown & Pilsbry (see Olsson 1932), and much less with the type species *D. concentrica* (Born). The living species closest in shape appears to be *D. dunkeri* Philippi from west-central America, but this is smaller and has a slightly pouting lunule. These comparisons are based on the Chepu fossils; less certain is their relationship with the type of *Artemis semilaevis* Philippi, which was described from Navidad and recorded also from Curauma.

Philippi's illustrations show a shell agreeing in shape with the Chepu specimen, but smaller (43 mm).

Venus baylii Hupé, based on a poorly preserved specimen from Chiloe Island and attributed to *Artemis* by him and by Philippi may be an older name for the Chepu species, but it has never been figured and must be classed as indeterminable.

Dosinia is recorded mainly from the Navidad Stage, but the living species *D. ponderosa* (Gray) occurs in the Coquimbo Stage (Herm 1969). *Dosinia* no longer lives off Chilean coasts, but two species reach their southern limits in Peru.

Genus *AMIANTIS* Carpenter 1864

Type species (by monotypy): *Cytheria callosa* Conrad, Recent, California.

Subgenus *EUCALLISTA* Dall 1902

Type species (by original designation): *Cytherea purpurata* Lamarck. Recent, Brazil.

Amiantis* (*Eucallista*) aff. *domeykoana (Philippi), figure 5*i*, plate 27, figure 8*b*.

Venus Domeykoana Philippi 1887: 123, pl. 21, fig. 2.

V. crassa Philippi 1887; 123, pl. 21, fig. 1 (*non* Gmelin 1790, *nec* Quoy & Gaimard 1835).

Amiantis crassa (Philippi); Ihering, 1907: 349.

A. domeykoana (Philippi); Herm, 1969: 124, pl. 12, fig. 1–3.

Philippi's names were both based on specimens from La Cueva, differing in inflation, robustness of hinge, and height of shell and beaks, differences which Herm (1969: 125) has shown to be within the range of variation of a single species. Thanks to the kindness of Dr D. Herm, Munich, well-preserved topotypes have been available for comparison with the Chiloe specimens.

Philippi's figures of the hinge allow a more confident assessment of generic affinity than is the case with most of the species he figured. They show a strongly ornamented nymph and dentition that corresponds very closely to that of *Cytherea purpurata* Lamarck, type species of *Eucallista*, now generally ranked as a subgenus of *Amiantis*, for instance by Keen (1969).

Four specimens from Localities B and E include one from each that shows the hinge characters of *Eucallista*. The outline is not preserved, but the hinge and beaks are intermediate between those of Philippi's two nominal species, as figured by him. They are considerably heavier in build and have thicker shells and more massive hinge plates than Recent specimens of *A.* (*E.*) *purpurata* from Brazil and the Tertiary *A.* (*E.*) *laziarina* Ihering (1907, p. 414) from Argentina, but what ornament is preserved is similar to that of the living species. The Chepu shells are smaller than topotypes of *A. domeykoana* from La Cueva and appear to have been less circular in outline and thus intermediate between the Coquimbo and living species (figure 8); their right valve dentition also differs in details that may prove to be of systematic significance.

Although *A.* (*Amiantis*) *callosa* is a common bivalve on the west coast of North America today, the subgenus *Eucallista* is now restricted to the Atlantic coast of South America. In the Chilean Tertiary, therefore, *Eucallista* could be considered a notable member of the 'Atlantic' element. Although Möricke (1896) and Herm (1969) considered the Atlantic element to distinguish the fauna of the Navidad Stage (Miocene) from that of the Coquimbo Stage (Mid Pliocene) which had a more 'Pacific' character, *Eucallista* is an exception to this generalization, and it is not recorded in the Navidad or typical Coquimbo beds, apparently first appearing at Chiloe Island, well to the south, in Lower Pliocene time and only extending north to La Cueva in the Uppermost Pliocene.

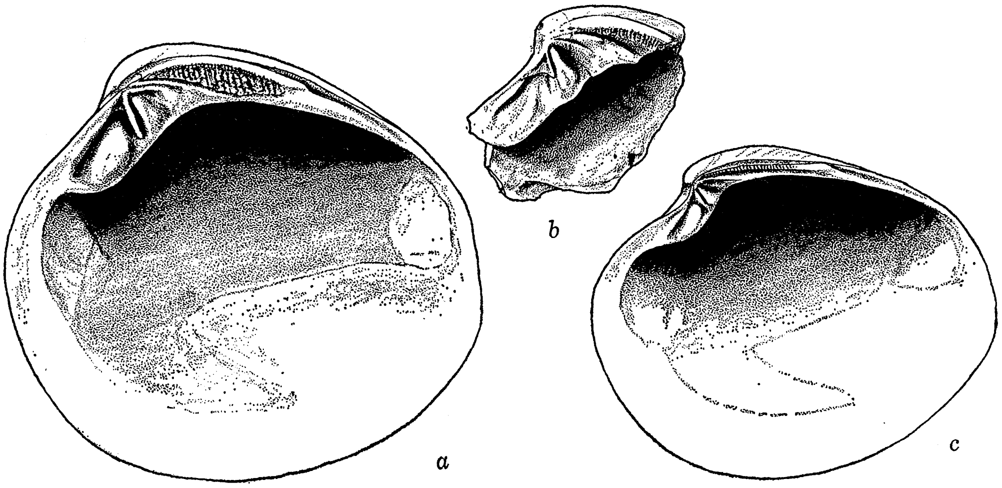

FIGURE 8. Fossil and recent species of *Amiantis* (*Eucallista*); right valves. × 1. *a*, *A.* (*E.*) *domeykoana* Philippi. La Cueva, Chile, Coquimbo Beds, Upper Pliocene (WM 9492, coll. D. Herm, 1965). *b*, *A.* (*E.*) aff. *domeykoana* Philippi. Chepu, Locality E (WM 9495). *c*, *A.* (*E.*) *purpurata* Lamarck. Bertioga, Brazil, Recent (WM 10).

Family MACTRIDAE

Genus *MULINIA* Gray, 1837

Mulinia sp., figure 5*g*.

Several valves 10 to 12 mm long in concretionary sandstone from Locality C and a smaller valve from Locality E have the general facies of *Mulinia lateralis* Say, a living species on the Atlantic Coast of the United States of America, and agree quite well in shape and sculpture with the Navidad shell described as *Mactra ignobilis* Philippi, but are somewhat smaller. Philippi, however, listed 29 species of Cenozoic '*Mactra*' from Chile, and revision of surviving type specimens of these and of the living nominal species would be necessary for a confident identification (see Herm 1969, p. 117). Other species that appear closely related are *Mactra garretti* Ortmann (Patagonian) and *M. irizari* Wilckens 1911 (Seymour Island, Tertiary). A hinge has been developed in a Chepu specimen, supporting reference to the genus *Mulinia* in which most living Chilean Mactridae are classed. *Mulinia* apparently ranges from Miocene to Recent in Chile.

Mactra (? ***Micromactra***) sp.

An imperfect left valve from Locality E (WM 10607, *ca.* 32 mm long, 23 mm high, inflation 4 mm) is superficially similar to the Californian Recent species *Spisula falcata* (Gould). What can be seen of the hinge, however, is mactroid, not spissuloid, in the sense of Dall (1895) and Marwick (1948). As the exterior is badly decorticated, no attempt has been made to match this specimen with Philippi's illustrations.

Family Solenidae

Genus *SOLEN* Linn.

Solen aff. ***crucis*** Ihering, figure 5*h*, *l*; figure 9*a*, *b*.

Solen crucis Ihering, 1907, p. 318, pl. 12, fig. 83.

Double-valved specimens of *Solen*, apparently preserved close to where they lived, are abundant in the collections from Localities C (10 individuals) and D (8 individuals). One was prepared to show the hinge and muscle impressions of the right valve (WM 9496b); it has a single cardinal tooth in each valve, lacks laterals, the anterior adductor impression is impressed, showing radial ridges in front, and does not extend as far back as the ligament, and the pallial line has a conspicuous antero-ventral projection. These characters make it certain that *Solen* is represented and not *Ensis*, which alone is present in the Pliocene to Recent faunas of Chile and adjacent regions (*Ensis macha* (Molina)).

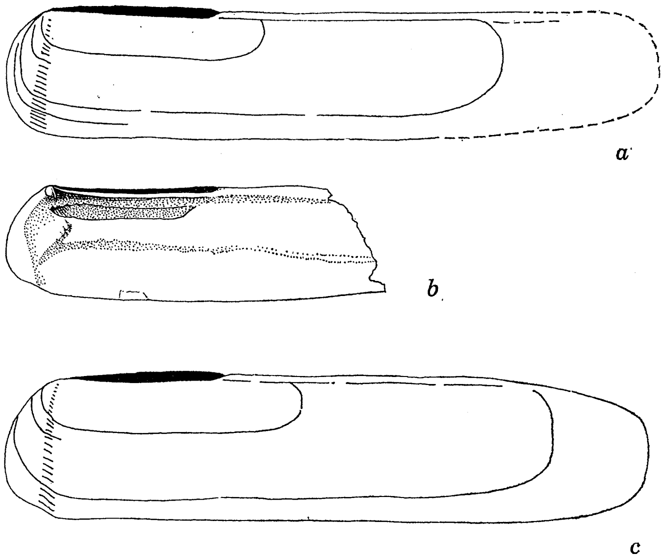

Figure 9. Outline sketches of *Solen*. Not to scale. *a*, *S.* aff. *crucis* Ihering. Chepu, Locality D (restoration based on WM 9496a). *b*, *S.* aff. *crucis* Ihering. Chepu, Locality D (interior of right valve, WM 9496b). *c*, *S. crucis* Ihering. Santa Cruz, Argentina (based on Ihering 1907, pl. 12, fig. 83).

The Chepu specimens are all broken but appear to have had a maximum length of *ca*. 100 mm. They resemble *S. crucis* in size and proportions, in the convex curvature of the anterior margin, and in having an anterior sulcus which, however, is not as strongly marked as in Ihering's figure. They are much larger, having a relatively longer ligament and more evenly rounded anterior margin, than *S. rosaceus* Carpenter (Recent, California to Mexico). Other West American species (Keen 1958) differ even more in proportions and outline. The Upper Cretaceous fossil *Solen elytron* Philippi, if indeed it is a true *Solen*, is much smaller, and the juvenile Navidad specimen figured by Philippi (pl. 34, fig. 10) has a more strongly developed anterior sulcus than the Chepu fossils.

Apart from Philippi's record of his *Solen elytron* from Navidad, neither *Solen* nor *Ensis* is known in the Chilean Miocene. *Ensis* appears in abundance in the Pliocene (Herm 1969, p. 94) and persists in the Recent fauna. Farther south *Solen crucis* occurs in the Upper Patagonian and in the Suprapatagonian of Santa Cruz, Argentina (Ihering 1907, p. 318).

Family HIATELLIDAE

Genus *PANOPEA* Menard, 1807

Panopea aff. ***ibari*** Philippi, figure 5*j*, *k*, figure 10*a*.

Panopaea ibari Philippi, 1887: 167, pl. 35, fig. 4.

Panopea ibari Philippi; Ortman, 1902: 152, pl. 29, fig. 5.

The collection includes a complete individual with closed valves from Locality E (WM 9497), part of a left valve from C (WM 10610) and a left valve hinge fragment from B (WM 10609).

Shell rather thin, equivalve, roughly equilateral, the beaks just in front of the mid-line, superficially resembling *Mya arenaria* Linnaeus. Elongate-ovate in outline, anterior expanded and rounded, posterior attenuate (unusually so for the genus), narrowly rounded, gaping at both ends but less so than in most *Panopea*. Beaks narrow, not prominent. Sculpture of smooth irregular concentric wrinkles and undulations, more regular towards the beaks, irregular and lower towards the ventral margin, with growth lines between them.

Interior of valve reflecting external undulations. Pallial line ill-defined; pallial sinus distinct, deep, narrowly rounded, extending forward in front of beaks. Anterior adductor scar obscure; posterior scar well defined, impressed.

WM 10610 shows the characteristic nymph and the worn hinge (WM 10609) agrees with that of *Panopea*. The matrix of WM 9497 was excavated near the right valve hinge line, exposing a single knob-like tooth below the beak. The nymph (visible in WM 10609) is similar to that of *P. goldfussi* Wagner but is separated from the dorsal margin by a much narrower groove and faces obliquely downward towards the plane of the commissure, not upwards as in most *Panopea*.

In some species of *Panopea* (and some species of *Mya*) the posterior margin of the valves is strongly truncated to produce a wide gape accommodating non-retractile siphons. In other species of these two genera, the posterior margins are elongated, attenuated, and rounded, and the gape correspondingly reduced. The depth of the pallial sinus, where it is known, appears to be inversely related to the amount of gape. It seems likely that the latter group of species, most if not all of which are known only as fossils, could retract their siphons to a greater extent than the former.

The group of species with rounded anterior margins and limited gape includes *P. woodwardi* v. Koenen and *P. heberti* Bosc (Oligocene, Europe), *P. whitfieldi* Dall and *P. parawhitfieldi* Gardner (Oligocene, Florida), *P. goldfussi* Wagner (Miocene, Maryland), *P. subsymmetrica* (Ortmann) (Magellanian, Punta Arenas), *P. nucleus* Ihering (Santa Cruz, Argentina), *P. nucleoides* Wilckens (Seymour Island, Tertiary), *P. panis* Ihering (Lower Patagonian, Argentina), *P. vetula* Philippi (Lota (?), Chile, Tertiary), and *P. ibari* Philippi (Magellanian, southern Chile). In New Zealand *P. wanganuica* Powell (Pliocene–Pleistocene) and *P. smithae* Powell (Recent), characterized by their deep pallial sinus, may also be members of this group, but are not typical in shape and gape; *P. smithae* is sympatric with *P. zelandica* Quoy & Gaimard, a member of the short-sinused group (figure 10*c*).

In none of the deep-sinused forms listed above is the anterior part of the valve so much extended, the posterior part so much attenuated or the beak so narrow as in the Chepu specimen here figured, but it agrees sufficiently well in outline with *P. ibari* Philippi to suggest affinity, allowing for the considerable amount of variation in shape in species of *Panopea*. The extremely deep pallial sinus, reaching forward in front of the beaks, is exceptional in *Panopea* but is almost matched in a specimen of *P. goldfussi* Wagner from the Calvert Miocene of Maryland (figure 10*b*).

P. ibari Philippi, described from Magellanes and Skyring Water, perhaps includes *P. subsymmetrica* (Ortmann) from Punta Arenas as a synonym. These localities are in the Loreto Formation, the type formation of the Magallanian Stage, classed as Oligocene (and/or Upper Eocene) by Hoffstetter *et al.* (1957) and thus considerably older than the Chepu fauna. *Panopea* is probably a bradytelic bivalve so that the difference in age does not necessarily deny affinity but great study will be required before the considerable number of specific names proposed for South American nominal taxa can be evaluated.

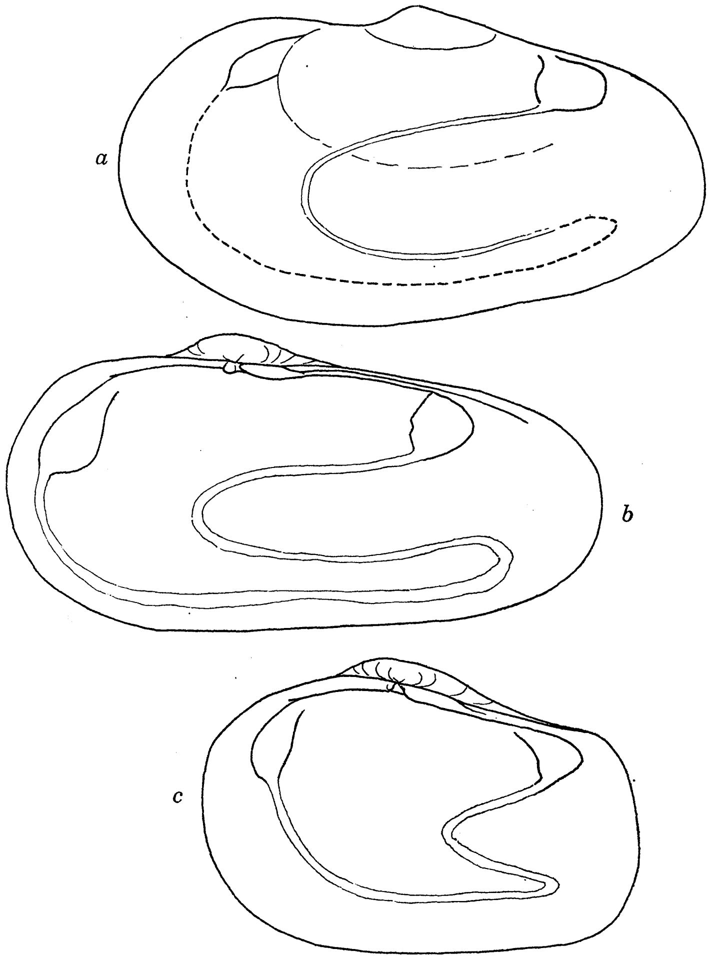

FIGURE 10. Outline sketches of *Panopea* showing differences in shape and pallial sinus. Not to scale. *a*, *P.* aff. *ibari* Philippi. Chepu, Locality E (WM 9497). *b*, *P. goldfussi* Wagner. Calvert Beach, Maryland, Miocene (WM 1308). *c*, *P. zelandica* Quoy & Gaimard. Kawhia, New Zealand, Recent.

The genus *Panopea*, present in Chile throughout the Tertiary, was represented by two short-sinused species, *P. coquimbensis* d'Orbigny and *P. oblonga* Philippi in the Pliocene (Herm 1969, p. 93) but is absent from the Pleistocene and no longer lives on the west coast of South America.

Class POLYPLACOPHORA

Order NEOLORICATA

Family Ischnochitonidae

? ***Ischnochiton*** sp.

A large intermediate valve, 28 mm wide, from Locality B, poorly preserved and incomplete (WM 10611), shows weak irregular radial ornament on pleural and lateral areas. It does not agree with either of the species of '*Chiton*' described by Philippi from the Coquimbo beds. According to Möricke (1896, p. 599), the presence of Chitons is characteristic of the Coquimbo Stage.

Class GASTROPODA

Subclass STREPTONEURA

Order ARCHAEOGASTROPODA

Family Patellidae

Genus *PATINIGERA* Dall, 1905

Patinigera aff. ***terroris*** (Filhol), figure 6*a*, plate 28.

Patella terroris Filhol, 1880, *Compt. Rendu*, xci; *Mission Isle Campbell*, **18**, p. 529.

Patinigera terroris (Filhol); Powell, *N.Z. Dep. Sci. Ind. Res.*, *Cape Exped. Bull.* **15**: 69.

A single specimen from Locality E (WM 10612), originally about 38 × 25 mm, with low profile, beak about 8 mm from anterior margin, and about 60 squamose ribs. Of the *Patinigera* species available for comparison it most closely resembles a series of *P. terroris* (Filhol) from Campbell Island.

P. delicatissima Strebel, from the Straits of Magellan and Falkland Islands, is 'a small thin species of low profile with delicately squamose ribs' (Powell 1951, p. 82) and thus also related to the Chiloe fossil but is smaller, more parallel sided, with more elevated and distinct ribs and narrower interspaces. The Chiloe fossil is very different from the coarsely sculptured *P. magellanicus* (Gmelin) and *P. deaurata* (Gmelin) (= *aenea* Martyn) now living in abundance on South Chilean coasts.

Patellidae have not been recorded from the Navidad Miocene. *Patella* spp. and *P.* (*Ancistromesus*) *fuenzalidai* Herm appear in the Middle Pliocene and *Patinigera* is first noted in the Pleistocene by Herm (1969).

Family Trochidae

Genus *TEGULA* Lesson, 1835

Subgenus *AGATHISTOMA* Olsson & Harbison, 1953

Type species (by original designation): *Trochus viridulus* Gmelin. Recent, West Indies.

Olsson & Harbison considered *Agathistoma* to be a tropical or warm-water group, but it appears to include *Tegula patagonica* (d'Orbigny), which ranges from Peru (Dall 1909) to Patagonia and is represented by specimens from Necochea on the Atlantic coast of Argentina in the Dominion Museum, Wellington.

Tegula (***Agathistoma***) aff. ***patagonica*** (d'Orbigny), figure 6*b*, *c*.

Trochus patagonicus d'Orbigny, 1840. *Voy. dans l'Amerique Merid.* **5**(3), p. 408, pl. 55, figs. 1–4

A single specimen from Locality E (WM 10613) has been compared with a large series of

T. patagonica from three localities in Argentina. It is slightly larger (width 19 mm) and has more spiral moniliform riblets and weaker denticles at the base of the aperture, which is separated from the sculptured edge of the base by a deeply excavated groove. These are specific characters, but the fossil is not listed as new as several Recent Chilean species of *Tegula* have not been compared. *T. patagonica* (type locality, Baie de San Blas, Patagonia) is recorded living from the Lobos Islands, Peru, by Dall (1909, p. 176), but Carcelles (1944) considers this record probably erroneous.

In addition to the above, there are two fragmentary specimens from the same locality, both lacking the base, differing in their broader and smoother ribs, which may represent a second species of *Tegula*.

No Trochidae of this type are clearly recognizable among the Chilean Tertiary Gastropods figured by Philippi (1887) and Möricke (1896). According to Herm (1969, p. 92), *Tegula* is not present in the Miocene (Navidad) beds of Chile, appearing in the Upper Pliocene as an immigrant faunal element from the north, and becomes abundant and widespread in the Pleistocene, but the two species he lists, *T. atra* (Lesson) and *T. luctuosa* (d'Orbigny), are members of the subgenus *Chlorostoma* Swainson and thus not close relatives of the Chepu fossil.

Calliostoma sp.

A small specimen (WM 10614, height 3.5 mm, diameter 3 mm), possibly immature, from Locality C, with rather strong spiral cords, one subsutural, two more on spire whorls, a fourth, peripheral, emerging from the suture, and 6 to 8 on the base, alternating in strength, is not unlike a juvenile *C. ligatum* Gould (California, Recent), but is not specifically determinable.

Calliostoma is not listed from the Pliocene and Pleistocene of Chile (Herm 1969).

Order MESOGASTROPODA

Family Cerithiopsidae

Cerithiopsis sp.

One specimen (WM 10615) from Locality E, lacking protoconch. Shell without varices, with three spiral cords of equal strength, beaded by nodules, between slightly channelled sutures, and a single narrow basal cord emerging at the suture; base otherwise unsculptured.

Numerous species of *Cerithiopsis*, representing several groups, are known from western America (Bartsch 1911, 1927) and *Cerithium pyrgiscus* Philippi, from the Tertiary of Lebu, Chile, is also probably a *Cerithiopsis* s.lat. Of the species compared, the Chiloe fossil is generally similar to *C. stejnegeri* Dall (Bering Island, North Pacific), but detailed comparisons would not be significant in such large genus.

Family Scalidae

Cirsotrema sp.

A single specimen (estimated height 6.5 mm, diameter 3.3 mm) from Locality B (WM 10616) has a well-defined basal plate, strong foliated varices and axial ribs, and smooth interspaces about 1.5 times the width of the ribs.

The many named generic and subgeneric taxa of Scalidae are badly in need of revision. The Chiloe shell belongs to a group having a basal plate but lacking spiral sculpture and with ribs that do not line up with those of the preceding whorl. *Stenorhytis* Conrad differs in shape and in its weak basal plate; in *Pomiscala* Iredale the narrower ribs are joined across the sutures and the basal plate is weak. *Gyroscala* Boury is described by Wenz (1940) as having a basal plate, not shown in his figure of the type (*Scala commutatum* Monterosato, after Kobelt) but shown by Bucquoy, Dautzenberg & Dollfus (1884, pl. 23, figs. 18, 19). *Coroniscala* Boury is based on a South American species *Scala coronalis* Deshayes = *S. magellanicum* Philippi, and Reeve's figure (reproduced by Wenz 1940, p. 798), quite closely resembles the Chiloe fossil, but Wenz's diagnosis mentions spiral sculpture. The Chilean fossil species of '*Scalaria*' described by Sowerby (1846) and Philippi (1887) either represent clearly different genera from the Chiloe specimen or are indeterminable. As a broad group, however, '*Scalaria*' disappeared from Chile before the Middle Pliocene and is absent from the Coquimbo Formation and from the Pleistocene beds.

Family Calyptraeidae

Crepipatella (?) sp.

An imperfect shell from Locality E (WM 10617), with terminal apex less coiled than in *C. dilatata* Lamarck, and lacking radial ribs. In a fracture, a septum with strongly convex margin is visible in cross-section, extending from left to right but separated from the external shell on the right by a narrow space representing the slit between the septum and the ventral apertural margin, as in *Crepipatella*.

Trochita sp.

An imperfect specimen from Locality B (WM 10618) is attributed to *Trochita* from its gently convex septum, judged by growth lines. The exterior surface is badly decorticated so that no ornament is visible.

Herm (1969) lists *Calyptraea* (including *Trochita*) as a genus absent from the Miocene of Chile, subordinate or absent in the Pliocene, which becomes dominant in the Pleistocene.

Another fragment of a limpet-like shell (Locality E) with apex considerably behind posterior margin shows a septum on its broken edge, but it cannot be matched among the Calyptraeidae with which it has been compared.

Family Naticidae

Genus *POLINICES* Montfort 1810

Type species (by original designation): *Polinices albus* Montfort = *Nerita mamilla* Linn. (Indopacific).

Subgenus *NEVERITA* Risso 1826.

Type species (by monotypy): *Natica josephinia* Risso (Mediterranean).

The species grouped in *Neverita* differ from species of *Polinices* s.str. in their depressed form, strongly prosocline outer lip, greatly inclined to the vertical, by a well-defined funicular lobe of callus and, in living species, by pigmentation, particularly of the umbilical callus, in contrast with the white callus of *P. albus* and its close relatives. The hypothesis that the living species now included in *Neverita* are monophyletic needs testing by anatomical comparisons of the living species, which are much more restricted in distribution than their Tertiary predecessors. Thus *Neverita* no longer lives on the west coast of South America or in New Zealand (where it was represented in the Upper Eocene by *P.* (*N.*) *pontis* (Marwick)). The subgenus survives in the Mediterranean (*josephinia* Risso), in the south-eastern United States (*duplicata* Say), California and Mexico (*recluziana* Deshayes), in the Indo-Pacific from Japan to Queensland (*didyma* Roeding) and in Australia (*incei* Philippi, *aulacoglossa* Pilsbry & Vanatta). *Glossalaux* Pilsbry, based on *Natica recluziana* Deshayes, has been used in Australia for *P. aulacoglossa*, but it is doubtful whether this further subdivision really groups related forms.

Polinices* (*Neverita*)** sp.nov. ?aff. ***secunda (Rochebrune & Mabille), figure 6*d*–*g*; figure 11*e*.

Compare:

Natica secunda Rochebrune & Mabille, 1885, *Bull. Soc. Philom. Paris* (Ser. 7), t. ix, p. 103.

N. omoia Rochbrune & Mabille, 1885, *Bull. Soc. Philom. Paris* (Ser 7), t. ix, p. 138.

N. obtecta Philippi, 1887, p. 82, pl. x, figs. 2*a*, *b*.

N. vidali Philippi, 1887, pl. 85, pl. x. fig. 17.

N. barrosi Philippi, 1887, p. 88, pl. x, fig. 9.

N. (*Neverita*) *obtecta* Möricke, 1896, pl. 566, pl. xi, figs. 26, 27.

N. darwini Ortmann, 1902, p. 189, pl. xxxiii, fig. 4. (*non* Hutton 1886, *nec* Philippi, 1887).

Polynices secunda Ihering, 1907, p. 155.

The nomenclature of Chilean Tertiary *Polinices* is most unsatisfactory. Rochebrune & Mabille's types were not figured and the identity of their 'two species' depends on a statement of Ihering (1907, p. 155) who, as first reviser, chose to use *N. secunda*, the name with page priority. Ihering, who presumably examined types, included *N. obtecta* Phil., *N. vidali* Phil., and *N. darwini* Ortmann (*non* Hutton) as synonyms. Möricke, ignoring Rochebrune & Mabille's names, synonymized *N. barrosi* Phil. with *N. obtecta*, restricting the latter to the Navidad form and describing the Coquimbo form as *N. obtectiformis*. This complex, which also includes *Natica pachystoma* Hupé, embraces the Chilean Tertiary representatives of *Neverita*, a subgenus no longer living on the west coast of South America. Farther north, in Peru, the *Neverita* recorded by Olsson (1932) from the Oligocene and Miocene appear more closely related to Central American species than to the Chilean ones.

Some of the names in the above list will almost certainly be revived when the South American Tertiary populations can be studied in a time sequence. Möricke (1896) differentiated the Coquimbo population (*objectiformis*) from the Navidad ones (*obtecta* Phil.), on the basis of the less pronounced groove on the umbilical callus, and this nomenclature is maintained by Herm (1969). *P.* (*N.*) *obtecta* has also been identified from the Ranquil Formation (Hoffstetter *et al.* 1957). The Chepu specimens differ from both these forms in their extreme development of callus on the base.

The specimens of *Polinices* (*Neverita*) represented in all five collections from Chepu district are probably conspecific, but those from Locality B are too incomplete for satisfactory comparison. The rest represent a large *Neverita*, up to 40 mm in diameter, with depressed, low-spired shell and prosocline outer lip greatly inclined from the vertical axis (figure 6*f*). The combined parietal and funicular callus is strongly developed, filling the umbilicus apart from a crescentic groove below the funicular expansion, extending on the base as a thick broad band, obscuring the abapical surface of the body whorl and dying out as a smear on the exterior of the anterior part of the outerlip. The anterior callus is fully developed on a specimen only 14 mm high

(Locality A). A shallow depression, where callus overlies the umbilical chink, separates the funicular callus from its anterior extension; in WM 9498 (figure 6*d*) this depression has been accentuated by crushing.

The extreme spread of callus anteriorly distinguishes the Chepu fossils from described species of *Neverita* and would justify their systematic separation were better material available. They are not intermediate between the Navidad and Coquimbo forms figured by Möricke, but are apparently a gerontic development. They may well be what Philippi (1887, p. 88) recorded as *Natica obtecta* from near Quetralmahue, Chiloe, but *N. chiloensis* Phil. from Cueva de Cucao to the south of Chepu is a species of *Polinices* s.str. not represented in the present collection.

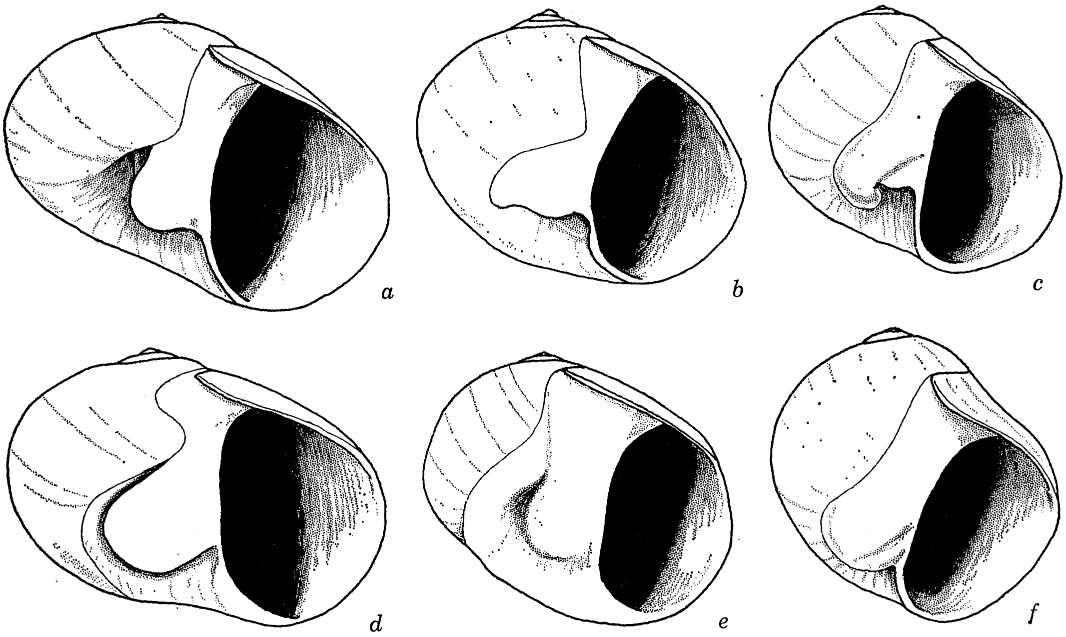

FIGURE 11. Callus development in species of *Polinices* (*Neverita*). Not to scale. *a*, *P.* (*N.*) *josephinia* (Risso). Mediterranean, Recent (WM 557). *b*, *P.* (*N.*) *duplicata* (Say). Georgia, U.S.A., Recent (WM 681). *c*, *P.* (*N.*) *recluziana* (Deshayes), California, Recent (WM 5056). *d*, *P.* (*N.*) *incei* (Philippi). Queensland, Recent (WM 7582). *e*, *P.* (*N.*) sp.nov. aff. *secunda* Chepu, Chiloe Island, Locality D (restoration). *f*, *P.* (*N.*) *obtecta* (Philippi). After Möricke (1896) pl. 11, fig. 23.

Differences in callus development in several species of *Nerevita* are illustrated in figure 11. In the living Mediterranean *josephinia* (*a*) the umbilical callus is restrained, forming a true funicle as in *Natica* and its allies, but this condition is secondary, judged by the predecessors of *josephinia* in the Miocene (*P.* (*N.*) *olla* (de Serres), etc.) in which the umbilicus is completely filled with callus (see Cossmann & Peyrot 1919). In the west Atlantic *duplicata* Say (*b*), the callus spreads to the base, as in *olla*, but leaves an open umbilical chink anteriorly. Similarly, in the variable *P. recluziana* Deshayes of California and Mexico (*c*) the spread of callus, extending well on to the parietal wall and base, leaves an anterior chink against the column, which is free of callus. Chilean Tertiary populations (*obtecta* = *secunda*) which have been compared with *recluziana* by Möricke (1896, p. 558) differ in the callus completely covering the umbilical groove (*f*). In the Chepu specimens an extended smear of callus is deposited widely over the base, lapping on the column (*e*). On a less extensive scale, the callus in *P.* (*N.*) *incei* Philippi (Recent, Australia) extends beyond the well-defined funicle area to form a basal band, thickening the column (*d*). Although *P. incei* is in this respect similar to the Chepu specimens it differs in shape and in its *posterior* extension of callus, reaching above (and thus doubling) the suture, so that close relationship is unlikely and the basal extension of callus apparently developed independently on opposite sides of the Pacific.

Order NEOGASTROPODA

Family Muricidae

Genus *OCENEBRA* Gray, 1847

Type species (by monotypy); *Murex erinaceus* Linnaeus (Recent, Europe).

In Opinion 886 (1969) the International Commission on Zoological Nomenclature has suppressed the generic name *Tritonalia* Fleming 1828, and placed the generic name *Ocenebra* on the *Official List of Generic Names in Zoology*. *Tritonalia* has been used by some recent authors sometimes instead of *Ocenebra* (e.g. Vokes 1964) and sometimes for a different group here classed in the subgenus *Crassilabrum* Jousseaume (Herm 1969).

Ocenebra (s.lat.) ***kuscheli*** sp.nov., figure 6*l*, pl. 28.

Material. An incomplete shell (holotype, TM 4844, in the New Zealand Geological Survey collection) and a fragmentary juvenile (TM 4981) from Locality B, Chepu district, Chiloe Island.

Description. A moderate-sized species of *Ocenebra* similar in general shape and apertural outline and in its open anterior canal to the Californian Recent species *O. circumtexta* Stearns, but closer to another Californian species, *O. interfossa* (Carpenter) in sculpture. Sculpture of strong spaced scaley spiral cords, three on spire whorls, eight on body whorl, with interspaces about equal in width on spire, becoming almost twice the width of the cords on the body whorl, where each bears a secondary interstitial spiral cord. Varices eight on each whorl, projecting and frilled on upper half of whorl but dying out on periphery and represented merely by scaley growth lamellae on the base. Outer lip thickened (probably with denticles but insufficiently preserved).

Remarks. The style of ornament is essentially similar to that of the Californian Recent species *O. interfossa* (Carpenter) or, for that matter, of the type species *O. erinacea* (Linnaeus). The restriction of varices to the adapical half of the body whorl seems distinctive. None of the living Panamic or Chilean species is close, and none of Philippi's illustrations of *Fusus* and *Murex* shows the diagnostic characters of the Chiloe fossil. Indeed, *Ocenebra* (= *Tritonalia*) has not been recognized in the Miocene and Pliocene of northern and middle Chile, and is first represented by the living species *O. buxea* (Broderip), in the older Pleistocene of Antofagasta-Mejillones (Herm 1969, pp. 18, 92). Herm considers *Ocenebra* to be a Panamic element that immigrated to Chile from the north after a faunal reconstruction at the beginning of the Pleistocene. The relationships of *O. kuscheli* suggest a similar origin at an earlier date.

Named after Dr G. Kuschel, entomologist attached to the Royal Society Expedition to Chile.

Subgenus *CRASSILABRUM* Jousseaume

1880. *Le Naturaliste* 1 (42): 335.

Type species (by original designation): *Murex crassilabrum* Gray = *Murex crassilabrum* G.B. Sowerby II, 1834. Recent, Chile.

Ocenebra (Crassilabrum) wattersi sp.nov., figure 6*h* to *j*, plate 28; figure 12*b*.

Material. The holotype (New Zealand Geological Survey collection, TM 4845) and an incomplete paratype from Locality E (TM 4982) and a juvenile from B (WM 4983).

Description. Similar to the *Murex crassilabrum* Sowerby 1834 (ex Gray M.S.), but larger, with relatively higher spire, and differing markedly in having only a single spiral keel, representing the uppermost of the three spiral cords developed in the Recent species (figure 12). Apertural varix greatly thickened, constructed of about 15 superposed frilled lamellae, the frills, due to radial corrugations, best developed below the periphery, on its adapertural face. Eight varices on body whorl, the first four almost as thickened as the apertural varix (but probably variable in this respect). Outer lip not denticulate. Peripheral spiral cord narrowly rounded; shoulder and base, between varices, lacking ornament apart from very faint irregular spiral undulations, corresponding with apertural corrugations.

Height (estimated) 50 mm; width 29 mm (holotype),

Remarks. Apart from having only one spiral cord, this species differs from *O. crassilabrum* Sowerby in being larger, in having fewer varices and a larger number of varices thickened, and in its finely corrugated aperture.

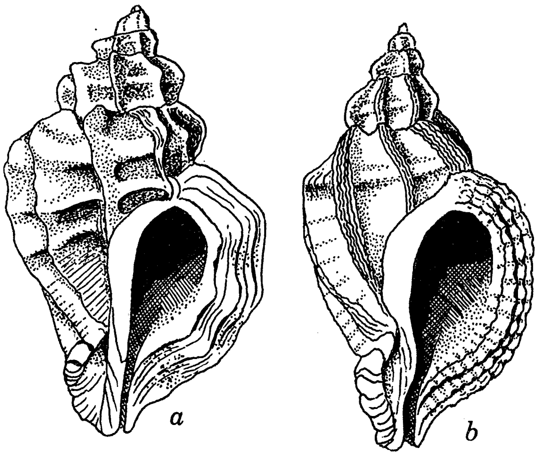

FIGURE 12. Recent and fossil species of the subgenus *Crassilabrum* Jousseaume. Not to scale. *a*, *Ocenebra* (*Crassilabrum*) *crassilabrum* (J. B. Sowerby II). Recent, Chile (Dominion Museum, Wellington, MF 15506). *b*, *O.* (*C.*) *wattersi* sp.nov. Chepu, Chiloe Island (restoration from type material).

The subgenus has hitherto been monotypic, but *Murex lamellifer* Philippi (1887, p. 56, pl. 3, fig. 22) from Matanzas (Navidad beds) is possibly a still older member. A close relation of the Recent *O.* (*C.*) *crassilabrum* (Sowerby) is recorded under the name '*Tritonalia crassilabrum* ssp.' from the older Pleistocene of the La Serena–Coquimbo district (Herm 1969, p. 53). The new species extends the stratigraphic range of *Crassilabrum*, which was presumably derived from Panamic stock, back into the Tertiary.

Genus *ACANTHINA* Fischer de Waldheim, 1807

Synonym: *Monoceros* Lamarck, 1822 (non Lacepède, 1798).

Wenz (1940) treats *Acanthina* as a subgenus of *Nucella* Röding 1798 but its distinctive characters justify the generic status granted by most American workers (Grant & Gale 1931; Abbot 1954; Keen 1958).

Acanthina crassilabrum (Lamarck)

Monoceros crassilabrum Lamarck 1816, *Encyc. Methodique* (Vers), pl. 396, fig. 2*a*, *b*, Liste, p. 2; Text, vol. 2, p. 333 (1830).

Acanthina crassilabrum katzi subsp.nov., figure 6*m* to *s*, plate 28.

Material. Some 35 specimens, some of which are incomplete, and many worn; the most abundant gastropod at all localities (A to E). The holotype (TM 4856) and figured paratypes (TM 4857, 4858) are from Locality E.

Description. Fossil populations of *Acanthina crassilabrum* (Lamarck), characterized by the persistence on the body whorl of numerous flat-topped squamous spiral cords, 18 to 20 in number, separated by interspaces that are generally narrower than the cords and sometimes linear. In the best preserved specimens the spiral cords are crossed by numerous growth lamellae, imbricating both ribs and interspaces; in worn specimens the lamellae are restricted to the interspaces. The spiral cords may be evenly developed or may alternate in strength, especially on the base. Inner lip with 9 to 11 denticles. In the two largest specimens, originally 29 mm high, low axial nodules are developed on the periphery of the last quarter whorl.

Comparisons. The form of *Acanthina* present at all localities at Chepu is apparently closely related to *A. crassilabrum* (Lamarck), a common and variable Recent shell on Peruvian and Chilean coasts. *A. crassilabrum* is the oldest name among a number of nominal taxa, the status of which is at present uncertain. The differences between the Chepu fossils and later populations of *A. crassilabrum* in the Coquimbo Beds and on modern coasts are here interpreted as subspecific.

On the coast of Chile *A. c. crassilabrum* appears to include the variants to which the trivial names *glabratum* Lamarck, *citrinum* Sowerby, *globulus* Sowerby, and *costatum* Sowerby have been applied. Some of these names have been retained as subspecies of *A. crassilabrum* by Carcelles & Williamson (1951), but as their ranges (between 27° and 38° S, perhaps to 48° S judged by specimens from Chiloe) overlap widely they do not appear to be geographic races in a strict sense. Another specific name, *A. acuminata* (Sowerby), based on a high-spired, well-sculptured shell from Valdivia, is treated as a sympatric species by Carcelles & Williamson ranging from 27° to 42° S.

Farther south, in the Magellanic Province, *Acanthina* is represented by a different form, *A. brevis* (Sowerby) (= *calcar* Martyn, figured in a work rejected for nomenclatural purposes), of which *A. imbricatum* Lamarck is apparently a synonym.

The forms of *Acanthina* present in the Middle Pliocene and Pleistocene of northern and central Chile have recently been revised by Herm (1969) who treats them all as subspecies of *A. crassilabrum*. Several of these 'subspecies' occur together at the same horizon but, whatever their systematic status, they indicate the morphological diversification of *Acanthina* during Plio-Pleistocene time. *Acanthina* was not present at all in the Miocene of Chile, so that the Chepu fossils extend its range back in time.

Individual specimens of *A. c. crassilabrum* living in exposed rocky situations commonly lose as adults the ornament of spiral cords present in young stages and their shells become greatly thickened. The specimens of *A. c. katzi* also include smooth thickened specimens but it is clear that they are not systematically distinct from accompanying sculptured specimens. *A. c. katzi* differs from *A. c. crassilabrum* and from other mid-Pliocene to Recent populations in its flat-topped spiral cords and narrow interspaces.

Genus *CHORUS* Gray 1847

Chorus* aff. *blainvillei (d'Orbigny), figure 6*u*, plate 28.

Monoceros blainvillei d'Orbigny, 1842, p. 116, pl. 6, figs. 18, 19.

Chorus blainvillei blainvillei (d'Orbigny); Herm, 1969, p. 133.

An imperfect specimen from Locality E (WM 10628), estimated to have been 58 mm high, has been compared with the type species of *Chorus* (*Monoceros giganteus* Lesson) and with the illustrations of fossil species published by Philippi (1887) and Herm (1969). The Chiloe specimen is smaller and narrower than *V. giganteus*, which is first known from the Upper Pliocene, with less inflated whorls, but has similar sparse spiral ornament. The body whorl embraces the penultimate whorl, giving a tangential suture, but becomes shouldered near the aperture, like d'Orbigny's type specimen (re-figured by Philippi 1887, pl. 5, fig. 2). It lacks the nodulation of *C. blainvillei nodosus* Möricke (Philippi, pl. 5, fig. 3) which is from Chiloe Island and is the only species Philippi considered common to Chiloe and Coquimbo, but fossil populations of *Chorus* are notoriously variable (Möricke 1896; Herm 1969) and large series would be needed to judge the importance of such differences. From *C. b. blainvillei* the Chiloe specimen differs mainly in its narrower shell and apparently higher spire.

Chorus, like *Acanthina*, is absent from the Chilean Miocene, becomes a dominant member of middle Pliocene communities, with several distinctive nominal species, of which only one (*giganteus*) survives the Pliocene and persists in the Recent fauna. The Chepu record extends the range of the genus.

Family OLIVIDAE

Genus *OLIVANCILLARIA* d'Orbigny, 1839

Subgenus *LINTRICULA* H. & A. Adams, 1853

Olivancillaria* (*Lintricula*) *tumorifera (Hupé), figure 6*t*, *w*, plate 28.

Oliva tumorifera Hupé, in Gay, 1854. *Hist. fisc. i polit. de Chile, Zool.*, Bd. 8, p. 218; Philippi, 1887 p. 72, pl. 8, fig. 9.

Ancillaria tumorifera (Hupé); Möricke, 1896, *N. Jahrb. min. geol. pal., Beil.-Bd.* 10, p. 572.

Olivancillaria tumorifera Phil.; Ihering, 1907, p. 514.

A single very imperfect specimen from Locality B (WM 10629) shows heavy parietal callus extending onto the spire and obscuring the protoconch, as is characteristic of the subgenus *Lintricula*. Only minor differences of outline distinguish the Chiloe specimen from that figured by Philippi (pl. 8, fig. 9) as *Oliva tumorifera* Hupé from the Navidad Beds, in which it is a characteristic element.

Recognition of *Oliva tumorifera* as a member of the distinctive subgenus *Lintricula*, of which the type *O.* (*L.*) *auricularia* (Lamarck) is now restricted to Brazil, emphasizes that *O. tumorifera* is an 'Atlantic' element in the Navidad faunas, in terms of the faunal analyses of Möricke (1896) and Herm (1969). *O.* (*L.*) *tumorifera* is a typical member of the Navidad fauna (Miocene); only in the Chepu fauna does it occur with such exclusively Pliocene genera as *Acanthina* and *Chorus*.

Genus *LAMPRODOMINA* Marwick, 1931

N.Z. geol. Surv. pal. Bull. **13**, p. 131

Type species (by original designation): *Oliva neozelanica* Hutton. Mid-Miocene–Pliocene, New Zealand.

Lamprodomina Marwick differs from Olivellinae (which it resembles in shape) in that the body whorl is divided into two zones by an encircling line separating a posterior segment, which is smooth and polished, from an anterior segment, which is dull as if encrusted by a thin wash of callus (Olsson 1956, p. 216). In some specimens the boundary is an incised line. The boundary line is not strictly spiral. In young shells it is on the lower half of the whorl, not far above the fasciole, and it climbs in older shells until in adults it emerges near the posterior end of the aperture (figure 13). It may rise quite steeply on the body whorl (and in some specimens steps up abruptly at prominent growth lines, figure 13*i*) until it is higher on the outer lip than on the inner lip, in large specimens reaching the upper suture so that the extension of fasciolar callus covers the whole aperture (figure 13*d*).

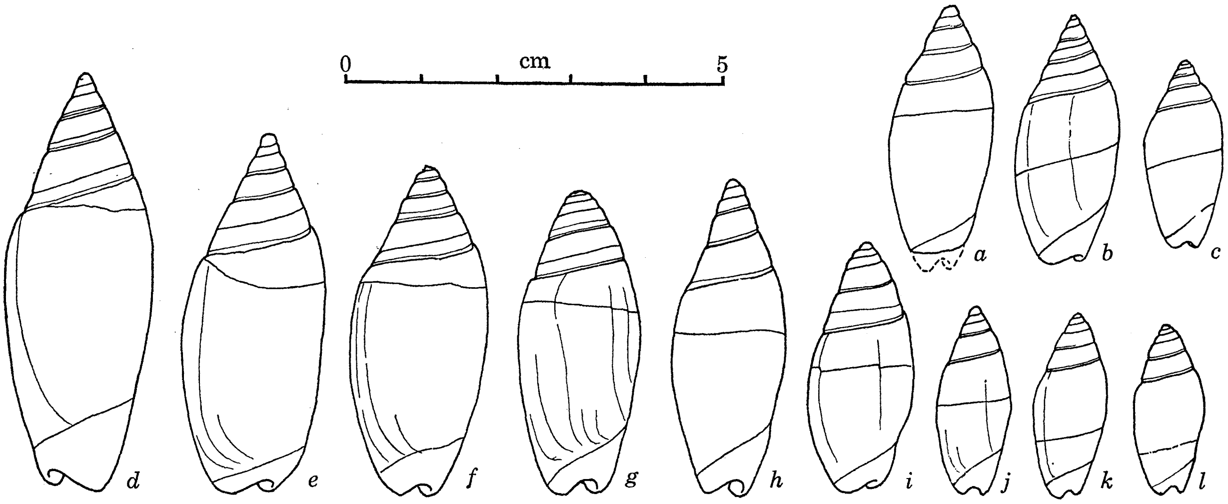

FIGURE 13. *Lamprodomina dimidiata* (Sowerby) (*a* to *c*) and *L. neozelanica* (Hutton) (*d* to *l*). Outline drawings to show the spread of the suprasiphonal fasciolar callus backwards across the body whorl during growth of the shell. *a*, *c*, Chepu; *b*, holotype, Navidad, after Sowerby; *d* to *l*, New Zealand Upper Miocene (*d*, *e*, *h*, Ethelton) and Lower Pliocene (*f*, *g*, *i*, *k*, *l*, Te Waewae Bay; *j*, Kaawa Creek).

Marwick (1931, p. 131), in proposing *Lamprodomina* as a subgenus of *Olivella*, distinguished it by the lack of a narrow spiral band, thinly enamelled with callus, that lies above the fasciolar callus band in the subgenus *Lamprodoma* Swainson. The upper side of this upper callus band is bounded by an incised groove, resembling the spiral band of *Ancilla* and *Baryspira* (depressed band of O. P. Olson 1956). Marwick failed to note that the missing posterior boundary of this upper segment of callus (later termed the 'suprasiphonal fasciolar segment' by A. A. Olsson 1956) is developed in a much higher position on the whorl, as illustrated in figure 13.

Olsson (1956, p. 159) recognized the extended callus band as characteristic of *Lamprodomina* and of certain groups of *Oliva* s.lat. (*Strephonella* Dall, *Omogymna* Martens, and, it may be added, *Anazola* Gray) and he therefore ranked *Lamprodomina* as a genus of the Olivinae. *Lamprodomina* has hitherto been considered endemic to New Zealand.

Lamprodomina dimidiata (Sowerby), figure 6*k*, *v*, plate 28; figure 13*a* to *c*.

Oliva dimidiata G. B. Sowerby I, 1846, p. 263; pl. 4, figs. 76, 77.

O. simplex Hupé, 1854, p. 217. Conch. pl. II, fig. 9.

O. dimidiata (Sowerby); Philippi, 1887, p. 73, pl. 8, fig. 14.

O. dimidiata Sow.; Möricke, 1896, p. 571.

Five specimens from Locality B, one from E, all imperfect, the largest (B) estimated to have been 24 mm in height. They agree with Sowerby's figure in shape and detail of fasciole. Five specimens with body whorls preserved all show a structural line dividing the broad band and separating it into two parts differing in texture, the anterior part representing a backward extension of the fasciolar callus, but in only one specimen is the boundary marked by an incised line. The broad anterior band of enamel and its boundary line were remarked on by Sowerby, Philippi and Möricke as distinguishing this species; Möricke further remarked that in his material the line varied in its position above the middle of the whorl. In the larger Chiloe specimens and in topotypes from Navidad supplied by Dr D. Herm it is relatively higher than in the smaller ones, just as in the New Zealand type species (figure 13).

L. dimidiata scarcely differs from the Mid-Miocene to Pliocene populations at present grouped in *O. neozelanica* except for the somewhat higher position, in shells of the same size, of the line marking the top of the fasciolar callus. The two are kept separate until adequate samples can be compared throughout their stratigraphic range. *L. neozelanica* and *L. dimidiata*, on opposite sides of the Pacific, are the only species of *Lamprodomina* so far recognized.

In Chile, *Lamprodomina dimidiata* is a characteristic species of the Navidad Beds (Möricke 1896, p. 571) and is present in the Ranquil Formation (Upper Miocene) but is not recorded from the Coquimbo Beds (Herm 1969). In New Zealand *L. neozelanica* ranges from the Middle Miocene (Lillburnian Stage) to Pliocene (Waitotaran Stage) and was one of the species that failed to survive the first Pleistocene glacial cooling (Fleming 1962).

Subclass OPISTHOBRANCHIA

Order PLEUROCOELA

Cylichna (s.lat.) sp.indet.

Two small fragmentary specimens (Localities A, B) a few millimetres in height.

Phylum ARTHROPODA

Class CRUSTACEA

Subclass CIRRIPEDIA

The balanids from Chepu were submitted to Professor W. Newman, Scripps Institution of Oceanography, University of California, San Diego, who supplied the following notes from his initial examination of them.

Balanus (Balanus) laevis var. **coquimbensis** Sowerby

Balanus coquimbensis Sowerby, in Chenu 1843, Illustr. conch. I (16), pl. 6; in Darwin, 1846, p. 264, pl. 2, fig. 7.

Professor W. Newman has identified this form from Locality E. It was first described from Coquimbo.

Balanus (Megabalanus) spp.

Professor Newman considers large specimens from Localities B and E resemble *B.* (*M.*) *psittacus* Molina, a living South American barnacle recorded as a fossil from Coquimbo, Navidad and other localities by Philippi, but additional specimens of *Megabalanus* from Locality C probably represent a different species.

Subclass MALACOSTRACA

Family CANCRIDAE

Cancer sp.indet.

Professor M. F. Glaessner, University of Adelaide, has identified a fixed finger of a left chela and a fragmentary dactylus of a right chela as *Cancer* sp.indet. *Cancer* occurs in the Recent fauna of Chile.

10. DISCUSSION

(*a*) *Conditions of deposition*

The fossils from Chepu District are preserved in poorly sorted sandstone locally containing conglomerate pebbles, which overlies an irregular surface of basement schist. They include species from a variety of near-shore communities.

Intertidal or shallow littoral rock dwelling epifauna is represented by *Ostrea*, *Anomia*, *Choromytilus*, *Modiolus*, *Ischnochiton* (?), *Patinigera*, *Tegula*, *Trochita*, *Ocenebra*, *Acanthina*, *Balanus* and perhaps the crabs and colonial Polychaete. This assemblage corresponds with two of the biotopes defined by Herm (1969, pp. 84–86) in his palaeoecological analysis of Chilean Pliocene and Pleistocene faunas, to include the inhabitants of exposed rocky coasts (Biotope 1) and more protected rocky coasts (Biotope 4). Compared with Herm's Pliocene associations in these two biotopes, the Chepu assemblage differs in the presence of *Choromytilus*, *Tegula*, *Trochita* (i.e. *Calyptraea* of Herm), *Crassilabrum* (*Tritonalia* of Herm) and *Ocenebra* which characterize the corresponding Pleistocene biotopes of northern and central Chile.

Herm's Biotope 2, the coarse shell debris of unprotected coasts, is not represented at Chepu, and this probably accounts for the complete absence of Pectinidae (*Chlamys*) and Turritellidae (*Turritella cingulatiformis* Möricke-*cingulata* Sowerby) which play an important role in a large number of Chilean Pliocene and Pleistocene faunas.

Infaunal organisms that lived in the accumulating sediment offshore, but probably in no great depth of water, are represented by *Epilucina*, *Dosinia*, *Amiantis*, *Mulinia*, *Solen* and *Panopea*. *Polinices*, *Chorus*, *Olivancillaria* and *Lamprodomina* represent the carnivorous gastropods normally living at the surface of such a community. Several communities may be combined in this list. Thus *Polinices* (i.e. *Natica* of Herm), *Amiantis* and *Dosinia* characterize adlittoral sands off the beaches of unprotected coasts (Herm's Biotope 3), while *Mulinia*, *Solen* and *Panope* and *Chorus* represent a deeper or more protected environment (inner sublittoral; Herm's Biotope 5 grading towards Biotope 6). The Chepu assemblages representing these environments differ from the corresponding Pliocene assemblages of more northern areas in the absence of *Chlamys*, *Turritella*, '*Fusus*' and several venerids (*Protothaca*, *Eurhomalea*, *Chionopsis*) and in the presence of *Solen*, *Epilucina*, *Olivancillaria* and *Lamprodomina*, which are apparently survivors from the Miocene.

The Chepu fauna includes inhabitants of intertidal and rocky shores that were carried offshore to join the shells of several animal communities living in accumulating sublittoral sediments in depths probably not exceeding 20 m below low tide-level. The better known fossil localities of northern and central Chile span a greater range of environments, so that the absence of genera or species from Chepu has less significance in discussion of geological age than absence of Chepu genera or species from more northern districts.

(*b*) *Other Tertiary fossils recorded from Chiloe*

Sowerby (1846) determined the fossils collected by Darwin on the east coast of Chiloe (within 23 km (20 mi) of Castro). Hupé (1854) described four more species collected by Gay from Chiloe. Philippi (1887, p. 250) gave a combined list of these early discoveries at Chiloe and the Guaitecas Islands to the south, in which he grouped the island of Huafo (Guafo), together with later collections he had received from Chiloe.

The following list includes the species of Mollusca and Cirripedia recorded from Chiloe with an attempt to modernize generic classification. Some of the species that Philippi classed in broad Lamarckian genera were reclassified by Ihering (1907) and later authors; the Mitridae, for instance, by Cernohorsky (1970). Others have been allocated to genera tentatively and with variable confidence from Philippi's and Sowerby's figures. Detailed localities and collectors are extracted from the systematic sections of Philippi's text. For those marked T, Chiloe appears to be the type locality. Philippi's classification is given in parentheses.

BIVALVIA

Argopecten purpuratus (Lamarck) (= *Pecten rudis* Sowerby). Chiloe (Sowerby, in Darwin).
T *Chlamys tenuicostatus* (Hupé) (*Pecten*). Faluns de Chiloe (Gay).
T *C. simpsoni* (Philippi) (*Pecten*). Ranquil, near Ancud (Simpson, Martin) and Huinimo (Diaz).
Nuculana (*Saccella*) ? *cuneata* (Sowerby) (*Nucula*). Ranquil, near Ancud.
T *Malletia volkmanni* (Philippi). Chiloe (Volckmann).
T ? '*Teredo*' *diazi* Philippi. Chiloe, with fossil wood (Diaz).
'*Teredo*' *gregaria* Philippi. Near Ancud.
T *Tellina* (s.lat.) *oblonga* (Sowerby). Chiloe, eastern coast (Darwin).
T ?*Dosinia baylii* Hupé. Chiloe (Gay).
T '*Venus*' *roualti* Hupé. Chiloe (Gay).
T ?*Chione* (?*Lirophora*) *sulculosa* (Sowerby) (*Cytherea*). Chiloe, eastern coast (Darwin).
C. (?*Ameghinomya*) *meridionalis* (Sowerby) (*Venus*). Ranquil, near Ancud.
T ?*Protothaca chiloensis* (Philippi) (*Venus*). Near Ancud (Martin).
T ?*P. uncinata* (Philippi). Chiloe (Gay).

GASTROPODA

Turritella affinis (Hupé). Chiloe (Gay).
T. breantiana d'Orbigny. Chiloe (Martin, Hohmann, Simpson).
T. chilensis Sowerby. Chiloe.
T *Crepidula coriocella* Philippi, Cueva de Cucao (Philippi Jr).
T *Polinices* (s.lat.) *striolata* (Sowerby). Chiloe, eastern coast. (Darwin).
P. (*Neverita*) *secunda* Rochebrune & Mabille (*Natica pachystoma*; *N. obtecta*). Ancud (Hohmann); Cucao (Philippi Jr); near Quetralmahur, Chiloe (Martin).
T *P.* (?*Polinella*) *chiloensis* Philippi (*Natica*). Cueva de Cucao (Philippi Jr).
T *Natica* (?*Stigmaulax*) *pumila* Sowerby. Chiloe, eastern coast. (Darwin).
T *Distorsio* (*Rhysema*) *thersites* (Philippi) (*Tritonium*). Ancud, fairly common.
?*Kelletia subreflexa* (Sowerby) (*Fusus*). Ancud (Martin).

T ?*Nassarius chattertoni* (Philippi) (*Buccinum*). Cueva de Cucao (Philippi Jr).
Lamprodomina dimidiata (Sowerby) (*Oliva*). Ancud; Cucao.
T *Imbricaria chiloensis* (Philippi) (*Mitra*). Cueva de Cucao (Philippi Jr).
T *Mitra martini* Philippi (non Boettger, 1882). Near Ancud (Martin).
Miomelon domeykoanus (Philippi) (*Voluta*). Chiloe.
Belophos (?) *turbinelloides* (Sowerby) (*Fusus* = *Pleurotoma turbinelloides* Sowerby, non Reeve). Cueva de Cucao (Philippi Jr).

CIRRIPEDIA

Balanus varians Sowerby. Ancud (Martin).
T *B. hohmanni* Philippi. Ancud (Hohmann).

The above list has little in common with the list of fossils here reported from Chepu district (table 1). *Lamprodomina dimidiata* is the only Chepu species identified with confidence that has previously been reported from Chiloe, but the Chepu species of *Dosinia*, *Polinices* and *Balanus* could perhaps be conspecific with those previously reported from the island. Several of the remaining species also occur in the Navidad or Ranquil formations of central Chile. The contrast between the Chepu assemblage and those previously sampled from Chiloe is emphasized by the records of *Miomelon*, *Turritella* and *Chlamys simpsoni* as common at Chiloe. On the other hand, common genera at Chepu (*Solen*, *Panopea*, *Acanthina*) are not known from other localities. *Chlamys simpsoni* (Philippi), described from a Chiloe specimen, is a Pliocene species in central Chile (Herm 1969, p. 102), but it is an open question whether the Chepu fauna is contemporary with the faunas of different ecological facies represented by the collections of Darwin, Hupé and Philippi from other parts of Chiloe, which previous authors (e.g. Möricke 1896) included in the Navidad Stage (Miocene). As shown below, the Chepu fauna appears to be younger than typical Navidad faunas.

(*c*) *Relations with Navidad and Coquimbo faunas*

Möricke (1896), Herm & Paskoff (1967) and especially Herm (1969) have contrasted the fossil content of the Navidad (Miocene) and Coquimbo (Mid to Upper Pliocene) stages in Northern and Central Chile. Herm, in particular, has discussed the faunal changes from Miocene to modern times and the development of the present marine faunal provinces.

The generically diverse warm-water Miocene fauna contains Indo-Pacific and Atlantic elements, the latter apparently distributed by a continuous sea-way across the axis of the future Andean cordillera. The fauna of the Middle Pliocene beds of north and central Chile, deposited after an early Pliocene regression of the sea, is a cool-temperate one and stands in strong contrast with the Miocene fauna through its generic impoverishment. Some of the surviving genera underwent bursts of speciation, and their species showed exceptional variability and occurred in large numbers, suggesting dense populations, and some developed giant forms. Immigrant genera in the Pliocene are of Pacific, generally Panamic, origin. In the Pleistocene, further genera had disappeared, the numbers of species were reduced, surviving genera were represented by different species from their Pliocene predecessors, some Pliocene immigrants formerly subordinate became ecologically dominant, and additional Panamic genera appeared for the first time (Herm 1969, pp. 87–92).

The contrasts between Miocene, Pliocene and Pleistocene faunas suggest rather abrupt changes (*Faunenumwälzungen*, Herm, 1969), but changes within the Pliocene successions – such as the disappearance of *Isognomon* and *Panopea* in the lower part and the appearance of *Mesodesma* in the upper part of the preserved Pliocene sequence – suggest that the faunal transformations were more gradual and that assemblages of intermediate character probably occurred during the interval represented by the sedimentary gap between the youngest Navidad (Upper Miocene, Tortonian) and the oldest Coquimbo beds (Middle Pliocene).

Table 1. Tertiary fossils from Chepu District, Chiloe Island

	locality				
	A	B	C	D	E
Coelenterata					
Oculina remondi Philippi	.	.	.	.	×
Bryozoa (indet.)	.	.	.	.	×
Mollusca bivalvia					
Choromytilus cf. *chorus* (Molina)	.	.	.	.	.
Modiolus cf. *eiseni* Strong & Hertlein	.	×	.	.	.
?*Xenostrobus* sp.	.	.	×	.	.
Anomia sp. ? cf. *crepiduliformis* Philippi	.	.	.	.	×
Crassostrea sp.	×	.	.	.	×
Epilucina cf. *promaucana* (Philippi)	.	.	×	.	.
Dosinia aff. *semilaevis* (Philippi)	×	.	×	.	.
Amiantis (*Eucallista*) aff. *domeykoana* (Philippi)	.	×	.	.	×
Mulinia sp.	.	.	×	.	×
Mactra (?*Micromactra*) sp.	.	.	.	.	×
Solen aff. *crucis* Ihering	.	.	×	×	.
Panopea aff. *ibari* Philippi	.	×	×	×	.
Mollusca polyplacophora					
?*Ischnochiton* sp.	.	×	.	.	.
Mollusca gastropoda					
Patinigera aff. *terroris* (Filhol)	.	.	.	.	×
Tegula (*Agathistoma*) aff. *patagonica* (d'Orbigny)	.	.	.	.	×
Calliostoma sp.	.	.	×	.	.
Cerithiopsis sp.	.	.	.	.	×
Cirsotrema sp.	.	×	.	.	.
?*Crepipatella* sp.	.	.	.	.	×
Trochita sp.	.	×	.	.	.
Polinices (*Neverita*) sp.nov. ? aff. *secunda* (Rochebrune & Mabille)	×	?	×	×	×
Ocenebra kuscheli sp.nov.	.	×	.	.	.
O. (*Crassilabrum*) *wattersi* sp.nov.	.	×	.	.	×
Acanthina crassilabrum katzi subsp.nov.	×	×	×	×	×
Chorus aff. *blainvillei* (d'Orbigny)	.	.	.	.	×
Olivancillaria (*Lintricula*) *tumorifera* (Hupé)	.	×	.	.	.
Lamprodomina dimidiata (Sowerby)	.	×	.	.	×
Cylichna (s.lat.) sp.indet.	×	×	.	.	.
Annelida polychaetia (indet.)	.	×	.	.	.
Arthropoda crustacea, cirripedia					
Balanus sp.indet.	×	×	×	.	×
Malacostraca					
Cancer sp. indet.	.	×	.	.	.

Herm, indeed, with some knowledge of the Chepu fauna at the time he wrote, noted that the sedimentary gap decreases in intensity to the south of the area he described, and that Lower Pliocene faunas there document the transition between Miocene and Mid-Pliocene.

The Chepu fauna (Table 1) combines elements of Navidad and Coquimbo assemblages that are not known to occur together in more northerly districts (figure 14). Some of the genera recorded from Chepu (*Modiolus*, ?*Xenostrobus*, *Mactra*, *Mulinia*, *Calliostoma*, *Cerithiopsis*, *Cirsotrema Cylichna*, Polychaeta, *Cancer*) are not further discussed because of inadequate identification or uncertain geological history in Chile. The rest are considered in terms of the geological ranges given by Möricke (1896) and Herm (1969). The genus *Panopea* is known to range from Miocene to Middle Pliocene in Chile and all that may be said of the Chepu form, which is here compared with Lower Tertiary species, is that it is unrelated to known Middle Pliocene forms and thus

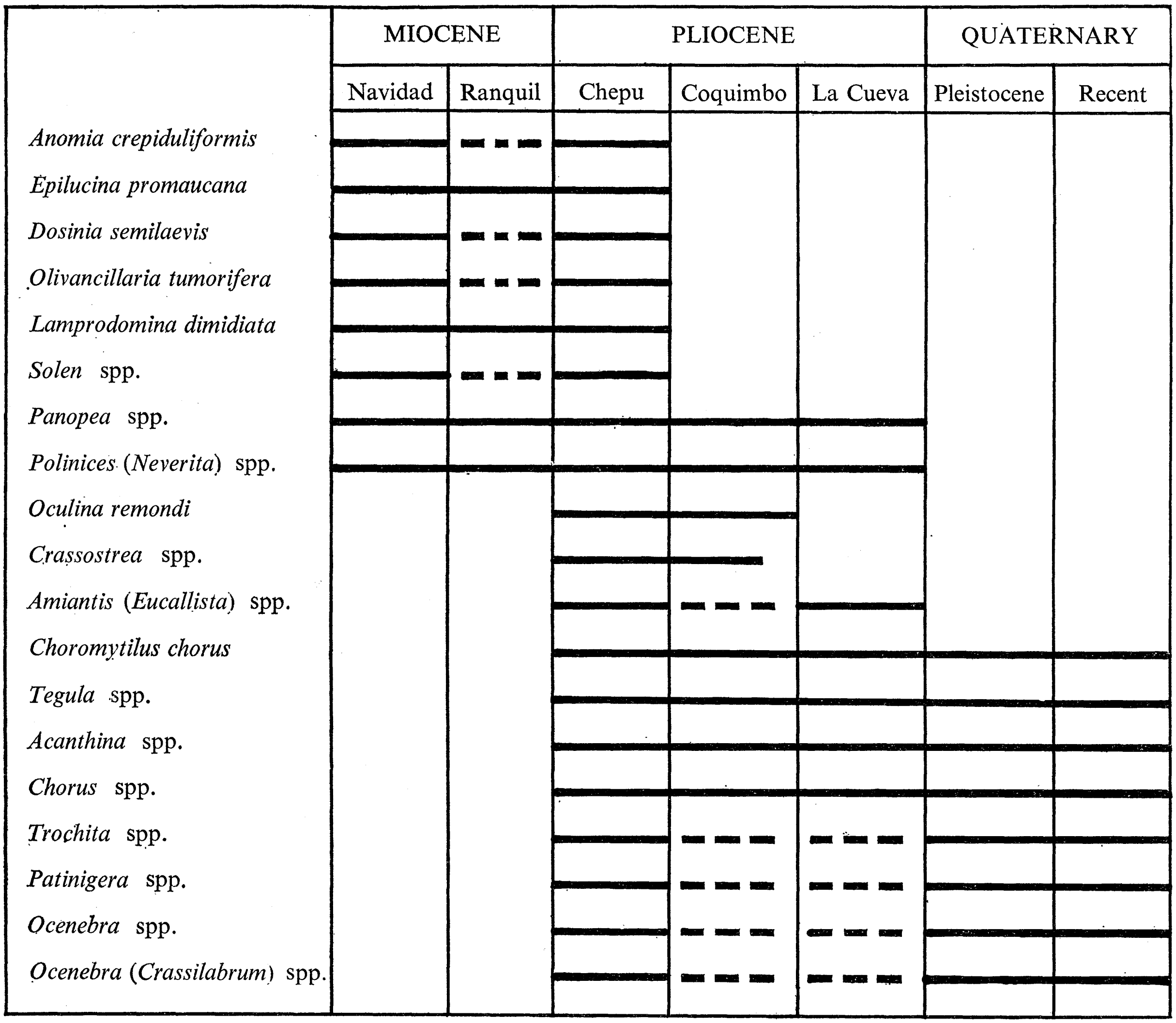

FIGURE 14. Stratigraphic range of significant fossil invertebrates of the Chepu assemblage in the Miocene to Recent faunas of Chile, showing occurrence together at Chepu of taxa otherwise restricted to the Miocene, Pliocene or Pleistocene. Data from Möricke (1896), Hoffstetter *et al.* (1957) and Herm (1969). Recorded ranges shown by solid line, presumed persistence by broken line.

suggests a greater age. The *Polinices* from Chepu, a distinctive form, also contributes no evidence of age.

Two species (*Olivancillaria tumorifera* and *Lamprodomina dimidiata*) are identical with well-known Navidad Miocene species. *L. dimidiata* is recorded from the Ranquil Formation (?Upper Miocene. These genera have not previously been recorded in younger beds in Chile. *Olivancillaria* persists in the Recent fauna of the Atlantic coast of South America. In New Zealand, *Lamprodomina* ranges from Middle Miocene to Lower Pliocene. *Solen*, too, is unknown in the Chilean Pliocene and the Chepu species is close to *S. crucis* of the Patagonian Miocene. Two other Chepu species (*Epilucina* cf. *promaucana* and *Dosinia* aff. *semilaevis*) are related to Navidad Miocene species and have no known younger representatives in Chile. *Anomia* ? cf. *crepiduliformis* may also be related to a Miocene species more closely than to the Pliocene members of the genus.

The taxa at Chepu hitherto known only from Pliocene or younger deposits are more numerous than those of Miocene aspect. *Oculina remondi* is otherwise restricted to several Mid-Pliocene (Coquimbo) localities in more northerly districts (Möricke 1896; Herm 1969). *Choromytilus* is not known from the Miocene, appears in the Mid-Pliocene, when it developed giant populations, and persists in the Recent fauna. *Crassostrea* also developed giant populations in the Middle Pliocene but failed to survive into the Pleistocene. The subgenus *Eucallista* appeared in the Upper Miocene or Lower Pliocene of Argentina (Entrerian Formation) and still persists on the Atlantic coast of South America, but is known on the Pacific coast only from Chepu and from the Upper Pliocene of La Cueva. According to Möricke the presence of chitons is characteristic of the Coquimbo Pliocene, but their absence from Navidad faunas must be attributed to lack of appropriate rocky shore biofacies in the Miocene deposits preserved. *Tegula* is also absent from the Miocene and is classed as an immigrant from the Panamic Province that developed as a prominent faunal element in the Upper Pliocene. *Crepipatella* (?) sp. belongs to a family (Crepidulidae) that occupied a subordinate role in Chilean Miocene faunas but its Pliocene species became rich in individuals, while *Trochita*, absent in the Miocene and subordinate or absent in the Pliocene, only became dominant in the Pleistocene. Patellidae are not known from the Chilean Miocene, probably owing to lack of the right biofacies, appearing first in the Middle Pliocene, and the genus *Patinigera* is first recognized in the Pleistocene. *Balanus*, subordinate in the Miocene, became dominant in shore facies in the Pliocene.

Acanthina and *Chorus*, unknown in the Miocene of Chile, first appeared in the mid-Pliocene, while *Ocenebra* and its subgenus *Crassilabrum* are not recorded prior to the Pleistocene; these are characteristic Panamic elements, prominent in the modern molluscan fauna of Chile, which Herm (1969) attributes to post-Miocene immigration. The Chepu representatives of *Acanthina*, *Ocenebra* and *Crassilabrum* differ from the Recent species recorded as fossils in central Chile and are thus probably older.

In summary, the Chepu fauna contains a considerable number of forms that did not appear (or did not become dominant) in more northerly districts until Middle Pliocene or Pleistocene time, together with a lesser number of Miocene forms that had disappeared by the Middle Pliocene. Several of the Pliocene–Pleistocene elements are restricted to rocky shores, so that their absence from the Miocene may be due to lack of suitable biofacies among Miocene deposits and should be given less weight in assessing the age of the Chepu fauna than less restricted forms.

(*d*) *Conclusions – age of the Chepu fauna*

The Chepu fauna, on the evidence available, is clearly intermediate in age between the Navidad and Coquimbo faunas of Central Chile, i.e. younger than Tortonian but older than Middle Pliocene. Although an uppermost Miocene age (Pontian or Messinian) cannot be ruled out, it is here considered to be Lower Pliocene.

No Lower Pliocene faunas have previously been recognized in Chile. In Argentina, the Entrerian (Parana) fauna (Ihering 1907), variously dated as very early Pliocene or late Miocene (Davies 1934) and the Pliocene Araucanian and Cape Fairweather faunas (Ortmann 1902; Ihering 1907) have little in common with the Chepu fauna.

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FIGURE 3. Coast near Punta Pulga, Chepu District, looking south, showing gently dipping Pliocene sandstone. Schist forms the base of the cliffs in the foreground. The rounded summits in the distance are the Metalqui Hills. (Photo by W. A. Watters.)

FIGURE 4. Coast at Punta Ahuenco, Chepu, looking north, showing stacks developed in Pliocene fossiliferous sandstone. (Photo by G. A. Knox.)

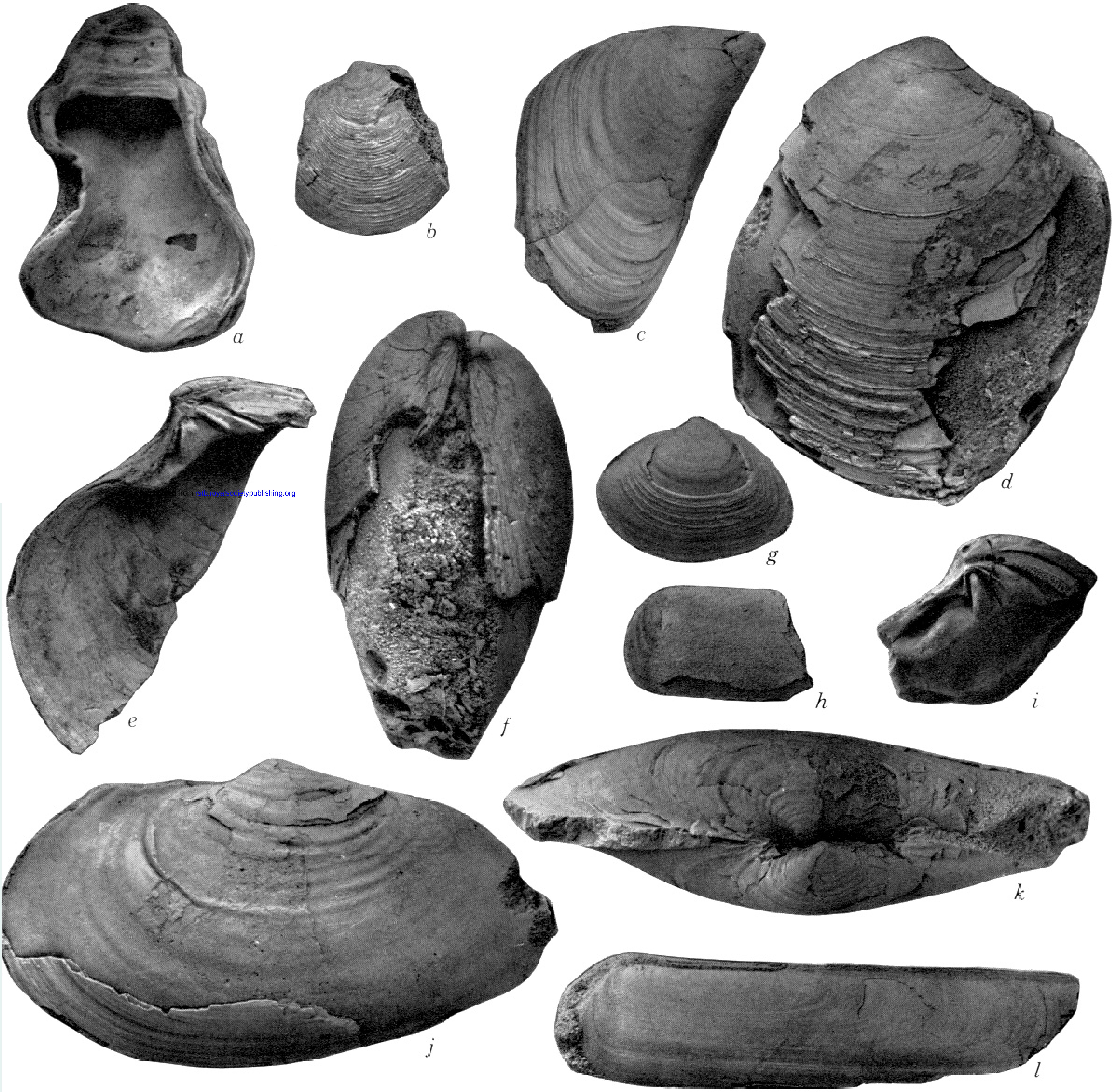

Figure 5. Pliocene Bivalvia from Chepu, Chiloe Island. (*a*) *Crassostrea* sp. (WM 10599a). (*b*) *Epilucina* cf. *promaucana* (Philippi) (WM 10601). (*c*) *Choromytilus* cf. *chorus* (Molina) (WM 10597). (*d* to *f*) *Dosinia* aff. *semilaevis* (Philippi) (WM 10603, 10602). (*g*) *Mulinia* sp. (WM 10605a). (*h*, *l*) *Solen* aff. *crucis* Ihering (WM 10608a, 9496a). (*i*) *Amiantis* (*Eucallista*) aff. *domeykoana* (Philippi) (WM 9495a). (*j*, *k*) *Panopea* aff. *ibari* Philippi (WM 9497). Figures × 1, except (*g*), × 2.5.

FIGURE 6. Pliocene Gastropoda from Chepu, Chiloe Island. (*a*) *Patinigera* aff. *terroris* (Filhol) (WM 10612). (*b*, *c*) *Tegula* (*Agathistoma*) aff. *patagonica* (d'Orbigny) (WM 10613). (*d* to *g*) *Polinices* (*Neverita*) sp.nov. ?aff. *secunda* (Rochebrune & Mabille) (WM 9498, 10619a). (*h* to *j*) *Ocenebra* (*Crassilabrum*) *wattersi* sp.nov., holotype (TM 4845). (*k*, *v*) *Lamprodomina dimidiata* (Sowerby) (WM 9730a, b). (*l*) *Ocenebra kuscheli* sp.nov., holotype (TM 4844); (*m* to *s*) *Acanthina crassilabrum katzi* subsp.nov. holotype (TM 4856), (*n*, *p*, *s*) and paratypes (TM 4857, 4858). (*t*, *w*) *Olivancillaria* (*Lintricula*) *tumorifera* (Hupé) (WM 10629). (*u*) *Chorus* aff. *blainvillei* (d'Orbigny) (WM 10628). Figures × 1.25, except *l*, × 2.5.