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Geology and Ecology of Taiwan Prehistory

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Quaternary System in Taiwan

Quaternary formations are scattered on Taiwan island and its satellite islets and can be grouped into three classes according to their origins and morphologies; *(a)* terrestrial facies; *(b)* marine facies; and *(c)* igneous and pyroclastic rocks. Among these, the terrestrial facies which is largely confined to the interior of Taiwan island and its coastal terraces and river banks, is composed of gravels, peats, lateritic soils, sands, and muds. The Huoyenshan conglomerates of the T'ouk'oshan group of the Lower Pleistocene is an exception, however; this is distributed among the hills of western Taiwan to form a peculiar badland topography. Among the marine facies, the T'unghsiao formation of the T'ouk'oshan group is distributed in the hill and terrace area of western Taiwan, on the Pescadores, and in the Taiting coastal range of eastern Taiwan. Later marine facies are located on the coasts of the main island of Taiwan and various islets nearby. The Quaternary igneous rocks and pyroclastic rocks are found on or in the Pescadores, the Tat'un and the Keelung volcanic groups, Ts'aolingshan near Tahsi, Chienshan near Hengch'un, and the Agincort, Crag, Pinnacle, Kuishan, and Small Botel Tobago islets.

Quaternary Subdivisions

The correlation of the Quaternary formations on Taiwan is indicated by Table 1. Accordingly, the Quaternary of Taiwan can be subdivided as follows:

B. Holocene Epoch
- 2. Peipinian Age
  - *b.* Anp'ingian Subage
  - *a.* Akungtienian Subage
- 1. Hualienian Age

A. Pleistocene Epoch
- 5. Milunian Age
- 4. T'ainanian Age
- 3. Tientzuhuian Age
- 2. Tananwanian Age
- 1. T'ouk'oshanian Age
  - *b.* Huoyenshanian Subage
  - *a.* T'unghsiaonian Subage

The T'unghsiaonian Subage formations are composed of sandstones, shales, and coral limestones, intercalated with thin layers of conglomerates. In addition to abundant fossils of molluscs, foraminifers, echinoids, bryozoans, corals, etc. from this Subage include stegodons *(Stegodon insignis, S.* cf. *orientalis, S. sinensis)*, elephants *(Elephas trogontherii, E. indicus buski)*, rhinoceri *(R. sinensis, R.* spp.),

saber-toothed tigers *(Felix* sp. cf. *Machairodus)*, wild cattle *(Bibos geron, Bibos* sp.), deer [*Cervus (Sika) taiuanus, C. (Deporetia) kazusensis, C.* sp., *Tragoceras* sp.], wild boars, and crocodiles. The mammalian fauna appears to be comparable with the Stegodon-Elephas fauna of South China, and its geological age can be placed from Villafranchian to Cromerian, or the so-called Pre-Glacial Age. The Huoyenshan formations of the Huoyenshanian Subage, of the T'ouk'oshanian Age, are composed of conglomerate strata, 600 to 1,000 metres in thickness, indicating a period of regression and apparently deposited during an orogenic phase. Its geological age can be compared with the Günz Glacial of Europe.

The Tananwanian Age is one of evident transgression, and its formations are composed of coral limestones and sandy-mud layers containing marine fossils of warm-water species. It is probably comparable in geological age with the Günz-Mindel Interglacial.

The Tientzuhuian is the stage of the second major regression in the Quaternary history of Taiwan, during which the shelf of the Formosa Strait lay completely exposed on its surface. It was an extended period of erosions, and the landscape is one of an old stage with low reliefs. The surface formation of this age is completely covered with lateritic soils, which has led Professor Tomita (1940) to refer to it as the Lateritic Hill, or the LH-plane. This feature suggests a probable correlation of this age with the Mindel Glacial of Europe, and it is probable that the laterization of the surface soils was due largely to extreme weathering during the subsequent warm periods.

The T'ainanian is another age of evident transgression; its sediments contain a large number of sands, muds, gravelly muds, and coral limestones mixed with marine fossils of warm-water species. Its geological age should correspond to the Mindel-Riss Interglacial according to its order of appearance. The marine facies of this stage form the higher coastal terraces (LT_1, LT_2, and LT_3). Formations of this age in the interior are of lateritic soil and gravels and are distributed along the banks and near the estuaries of the major rivers.

Disconformity is apparent between the Milunian and the T'ainanian Ages; the basal boulder beds of the Milunian Age (i.e. the Tulanpi boulders) developed above the erosion surface of the preceding age. This erosion surface was probably formed during the regression of the Riss Glacial Age. The corals and the mud and sand beds of the Milunian Age were formed on the Tulanpi boulders, indicating another group of transgressive deposits, probably corresponding in geological age to the Riss-Würm Interglacial. The Milunian terrace covering the Milunian corals is composed largely of gravels, sands, muddy sands, and muds. It includes two or three disconformities, suggesting that within the transgressive Milunian Age there were probably several episodic regressions, which may represent fluctuations of sea levels and are quite similar to those that occurred during the Würm Glacial in Europe. The Milunian formations form the higher coastal terraces, from LT_4 to LT_6, which are on the whole lower than the T'ainanian coastal terraces. At some localities the deposits of both the Milunian and the T'ainanian Ages form a common coastal terrace (e.g. the Milun Terrace near Hualien and the Tulan Terrace near T'aitung); in these cases the T'ainan formation constitutes the bulk of the terrace and the Milun formation covers

TABLE 1. CORRELATION CHART OF THE QUATERNARY PERIOD IN TAIWAN*

Epoch		Age	Interior Terrestrial Deposits	North Coast and Taipei Basin	T'aoyüan Prefecture Coast	Miaoli Prefecture Coast	Tainan and Kaohsiung Coast and Hills	Hengch'un Peninsula	Eastern Coast: Tulan Area	Eastern Coast: Ch'engkung Area	Eastern Coast: Hualien Area	Pescadores	Orogenic Movement	Shoreline	Volcanic Activity
Holocene	Late	Peipinian	Newest Terrestrial Deposits	Recent Marine Beds, Beach Deposits, Coral Reefs, and New Dune Sands	Recent Marine Beds, Beach Deposits, Coral Reefs, and New Dune Sands	Recent Marine Beds, Beach Deposits, and New Dune Sands	Recent Marine Beds, Beach Deposits, and Coral Reefs	Recent Marine Beds, Beach Deposits, Coral Reefs, and New Dune Sands	Recent Marine Beds, Beach Deposits, Coral Reefs, and New Dune Sands	Recent Marine Beds, Beach Deposits, Coral Reefs	Peipin Formation: Recent Marine Beds, Beach Deposits, and Coral Reefs	Recent Marine Beds, Beach Deposits, and Coral Reefs		(Regression)	
				(Shihsanhang Shell Mound) Old Dune Sands	Old Dune Sands	Old Dune Sands	(New Shell Mound)	Old Dune Sands	Old Dune Sands	×	Shell-bearing Gravel Member	Coastal Coral Breccia Beds	— Post-Hualien Phase		
				Kuohsingp'u Bed (Hsihsinchuangtzu Shell Mound)	Kuanyin Beds Gravel Beds	Gravel Beds	Akungtien Beds	Hungch'aik'eng Beds (K'enting Shell Mound)	×	×				Trans-gression	
				Gravel Beds			Akungtien Coral Reefs	Hungch'aik'eng Coral Reefs	×	Sanhsient'ai Coral Reefs	Mud Beds	Submarine Fossil Coral Reefs	— Hualien Phase	Regression	
	Early	Hualienian	Neisha Formation (Lower River Terrace Deposits)	Shenaok'eng Beds; Kengtzu-liao Coral Reefs; Basal Gravels; (Kung-hsia and Yüanshan Shell Mounds); Taipei Peats	× K'ant'outs'u Coral Reefs; Basal Gravel Beds	Lungkang Formation: (Wanli Shell Mound) Upper (Sandy Gravel); Middle (Sand and mud); Lower (Mud); Basal Gravel Beds	(Tahu Stage Shell Mounds) Dune Sands ×	Tashufang Land-shell Beds; Land-shell-bearing, White, Coarse-grained Sand Beds; K'enting Beds; Fengkang Coral Reefs; Basal Gravel Beds	× Cobble Beds	× Cobble Beds	Hualien Formation: × Marine fossil-bearing Sand Member; Hualien Coral Reefs; ×	Huhsi Beds: IV, III, II, I		Trans-gression	(Fluctuations in the Pescadores)
Pleistocene	Late	Milunian	Upper Chungli Formation (Higher River Terrace Deposits)	Sungshan Formation	×	Peishihl Formation: Sand and mud Beds; Basal Conglomerate Beds	Shihsanchia Beds; Newer Laterite-Gravel Beds; ×	× Wangsha Coral Limestone; Basal Gravel Beds	Milun Beds: Dark Red Gravel-bearing Sand and Clay Beds; Cobble Member; Granule Member; × Tulanpi Boulder Member	Dark Red Gravel-bearing Sand and Clay Beds; Cobble Member; Granule Member; Tulanpi Boulder Member	Milun Formation: Dark Red Gravel-bearing Sand and Clay Beds; Cobble Member; Granule Member, Foraminifer-bearing Sands; Coral Reef Member; Boulder Member	Hsiaomenyü Beds: Foraminifer-bearing Sandy Limestone; Alternation of Interlaced Ferruginous Quartz Sands and Muds	Tungning Orogenic Cycle — T'ainan Phase	Regression	Fluctuations
		Tainanian	Lower		×	×	T'ainan Formation: IV, III, II, I; Fengshan and Hsiaoliuch'iu Coral Limestones	Ehluanpi Coral Limestone	Tulanpi Beds: Upper (Gravel-Mud); Lower (Sand)	Bluish Gray Mud Beds; ×	Bluish Gray Mud Beds; ×	Basalt Flow	— T'aipei Phase	Trans-gression	Pescadores Volcanic Activity; Tat'unshan Volcanic Activity; Keelungshan Volcanic Activity
	Middle	Tientzu-huian	Tientzuhu Formation (=Link'ou Bed)	Link'ou Formation (Terrestrial)	Tientzuhu Formation (Terrestrial)	Tientzuhu Formation (Terrestrial)	Older Laterite-Gravel Beds	Older Laterite-Gravel Beds	Laterite-Gravel Beds (Terrestrial)		Laterite-Gravel Beds (Terrestrial)	Laterite		Major Regression	
		Tananwanian	Tananwan Formation T'aishan Phase	Tananwan Formation: Paotou-ts'u Facies, T'aishan Facies	Tananwan Formation: Paotou-ts'u Facies, T'aishan Facies	×	Kushan Coral Limestone	Higher Raised Coral Limestone	Higher Raised Coral Limestone		Milunshan Gravel Beds (?)	Alternations of Basalt Flows and Marine Beds	— P'englai Phase	Trans-gression	
	Early	T'ouk'oshanian	Huoyenshan Beds	Laoch'ienshan Formation; Huoyenshan Formation	Huoyenshan Formation	Huoyenshan Beds	Liukui Gravel Beds	Hengch'un Gravel Beds	P'inanshan Gravel Beds (?)		Milunpi Gravel Beds			Regression	
			T'unghsiao Beds: Yuch'ih Phase	T'unghsiao Formation	Yangmei Formation	T'ainan Formation: Nanwo Member; Wumeik'eng Member	Liushuang Beds; Erhch'unghsi Beds	Ssukou Beds; Hengch'un Limestone Beds; Maanshan Mud Beds	×	×	×	— ? — Marine Beds (Subterranean)	— Pre-P'englai Phase	Trans-gression	
Prepleistocene			(Underlain Beds)	Cholan Formation	Cholan Formation	? Cholan Formation	K'anhsialiao Formation	Hengch'un Formation	Takangk'ou Formation	Ch'imei Formation	?	Huayü Formation	↑		

* From Lin 1961, Fig. 9.

the surface. The terrestrial facies of the Milunian Age is also composed of laterite-gravel beds which form high terraces (LT_4 to LT_6) along the river banks and the estuaries. The Sungshan formation, in the Salt Lake deposits of the Taipei basin, is composed of muds and sands; and has yielded fossils of marine shells and foraminifers and *Balanus*. The age of its deposition can be placed within both the T'ainanian and the Milunian Ages.

The Hualienian formations (of the Hualien terrace) of Early Holocene are composed of basal gravels, raised coral reefs, coral breccia beds, shells, fossiliferous sands, and gravel beds. The Kunghsia and the Yüanshan shell-mounds of the Taipei basin, the Houlungti shell-mound near Miaoli, the Wanli shell-mound near Tachia, the Fantzuyüan shell-mound at Tachia, the Pakuashan shell-mound at Changhua, the various shell-mounds of the Tahu stage in T'ainan and Kaohsiung, and the shell-mounds at Liangwenkang, Shakang, Ch'ihk'an, and Chukaowan on the Pescadores, all appear to have been formed in the Hualien Age during a period of regression. The terrestrial facies of the Hualienian Age are composed of gravels, sands, and muds, forming the lower terraces of the modern rivers.

The deposits of the Peipinian Age include gravels, shell beds, pumice beds, dune sands, raised coral reefs, raised coral breccia beds, and foraminiferal beds; and recent beach deposits, dune sands, coral reefs, alluvial deposits, and lacustrine deposits. These are distributed near river beds, river banks, coasts, and lakes. The Hsihsinchuangtzu shell-mound in the Taipei basin, the Tap'enk'eng and the Shihsanhang shell-mounds on the southern bank of the Tanshui river, the shell-mound at the Hsinchu city, the Anp'ing jar shell mounds in T'ainan, and the shell-mounds with modern Chinese porcelains on the Pescadores all appear to have been formed during this age.

Evidences of Glaciation

The eustatic movement of the Taiwan Quaternary is probably a glacial eustasy associated with climatic changes, as elsewhere in the world. Major regressions indicate cold glacial periods, whereas major transgressions warm interglacial periods.

The following glacial formations seem to have been left during the Würm Glacial period (probably W4 for the most part, with some traces of W3). Cirque groups, arêtes, terminal moraines, central moraines, Rundhöcker, rocks and gravels with glacial scourings, *roches moutonnées*, Trogschluss, Zungenbecken, Talgletscher, and other glacial formations in the Nanhutashan region (el. 3740·3 m.) of the Backbone Range of Taiwan; cirque groups at Chungyangchienshan (el. 3703·4 m.), Lumoulamolushan (3270·9 m.), Pilushan (3370 m.), Tunghohuanshan (3416 m.), and Ch'ilaichushan (3558·9 m.); cirque groups, Kartreppen, morainic mounds, terminal moraines, glacial valleys, arêtes, cirque lakes, and *roches moutonnées* near Hsüehshan (3884 m.) in the Hsüehshan range; the small cirque groups between Tapachienshan and Hsiaopachienshan, and the cirque groups north of Tapachienshan, on the eastern slope of Tahsüehshan, and in the Yüshan range. The mechanical weathering is rapid and severe in the mountainous regions of Taiwan, and formations from older glaciations have not survived to this date.

The Formosan salmon (*Oncorhynchus formosanus* Jordan et Oshima) in the Upper Tachia river and the high-latitude flora and insects of the island can be considered as glacial relics surviving from the Pleistocene.

Land Bridge and Changes of the Shoreline

According to the topographic map of the Formosan Strait (Fig. 1) drawn by Niino and Emery (1961, fig. 4), the maximal depth of the sea water is 60-odd metres in most of the Strait, and the 100-m.-deep lines are seen only north of Keelung and in the Pescadores Channel. During the Günz, Mindel, Riss, and Würm 1 and Würm 2 maxima, if the sea level dropped more than 100 metres (according to European estimates), the shelf of the Formosa Strait must have been exposed, forming a land bridge between the island of Taiwan and the Chinese mainland, thus permitting movements back and forth of men and land animals and plants. During the interglacial maxima, on the other hand, the strait must have been covered with sea water of considerable depth, resulting in a temporary isolation of the island. Figures 2 through 9 are schematic representations of the land and water distributions on the Formosa Strait during the various periods of the Quaternary Period.

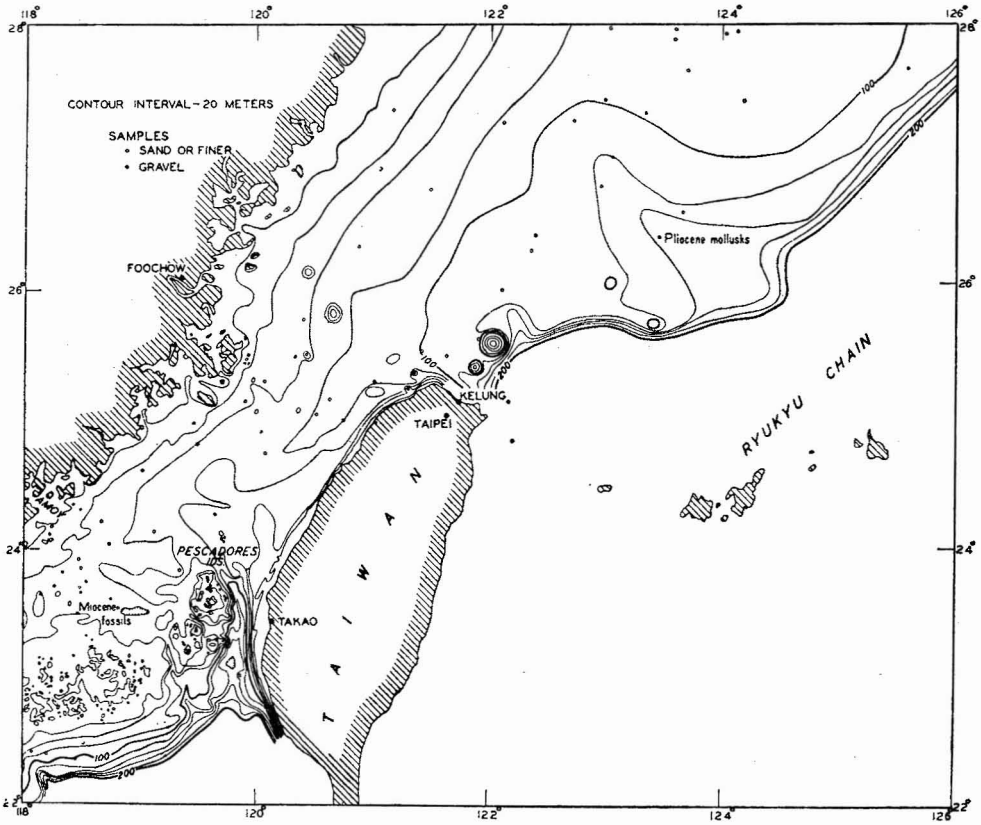

Fig. 1. Marine topography of Taiwan Strait and adjacent areas (after Niino and Emery 1961). Reproduced from *The Geological Society of America Bulletin*, **72**: 731–762, fig. 4 (with permission of the publishers).

These fluctuations of shorelines took place during the Holocene also. The recognized fluctuations in climate during the pre-Boreal, Boreal, Atlantic, sub-Boreal, and sub-Atlantic stages in Northern Europe and (known by different names) in North America were known to be associated with shoreline fluctuations, and the same phenomena appear in Formosa. In the T'ainan area, for example, at the maximum of the T'ainanian transgression the shoreline reached the foothills to the east of Hsinhua and near Kuanmiao, approximately the present 30- to 35-metre contour line. The neighbourhood of T'ainan was devoid of sea water, however, during the regressive period of the T'ainanian Age. In Early Holocene, at the maximum of transgression during the Tahu stage at the end of the Hualienian Age, sea water reached the present elevation of 7·5 to 10 metres, making an isolated islet of the T'ainan tableland. During the subsequent regressive interval, the various shell-mounds of the Tahu stage came into being along the then coasts and the drowned valleys. The Tahu shell-mounds can be further classified into a Niu-ch'outzu substage (Early) with cord-marked pottery; a Liuchiating substage (Middle) with combed black pottery; and an Antzu substage (Late) with plain red pottery. The topographical changes taking place in the T'ainan area during this regression are clearly indicated by the distribution of the shell-mounds of the three substages. After the formation of the Antzu shell-mounds, sea water began to be evacuated from the T'ainan area. A small transgression took place during the Akungtienian Subage of the Peipinian Age of the Upper Holocene, and sea water penetrated deep inland along the contemporary valleys. It probably reached the present elevation of 5 to 6 metres at the maximum of the transgression. The recent shell-mounds, in which the Anp'ing jars and other modern Chinese pottery have been found, were probably formed during the period of regression of the Akungtienian Subage or one of more recent date. According to early documents, a minor transgression took place in the T'ainan area in 1661 when the sea level was raised by about 3 metres, but this increase apparently lasted no more than a few years. Whether such records have geological significance cannot be determined.

The Taipei basin is a tectonic basin, formed during the Tientzuhuian Age when laterization of the land surface took place. Shortly after its formation the Taipei basin was submerged under sea water and became the ancient Taipei lake, which lasted from the Sungshan formation (that part of the T'ainanian Age when continuous deposits of sediments containing marine fossils occurred) through the end of the Milunian Age. After the Milunian the lake water drained away because of the collapse of the banks, and the whole region became a large swamp. A variety of lacustrine plants was abundant in the swamp which, in combination with plants washed into the basin as well as other native plants of the basin, subsequently forming the Taipei peats. In the peats have been found fossils of wild cattle and other mammals. Radiocarbon has dated the formation of the peats at about 4880 $\pm$ 300 years ago (Report no. WR-1016, Geochemistry and Petrology Branch, U.S. Geological Survey). Shortly afterward the basin surface tipped from the southeast toward the northwest, and the northwestern portions of the Taipei basin became a marshy and lacustrine region. Prehistoric men inhabited the neighbourhood of Yüanshan, on the eastern periphery of the lacustrine region, and their remains are known as the Kunghsia shell-mound. Another transgression took place,

FIG. 2. Palæogeographic map of T'ouk'oshanian Age, T'unghsiao Subage (Pre-glacial)

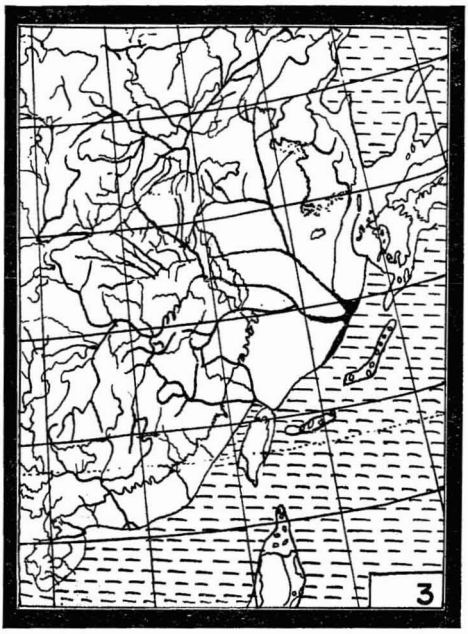

FIG. 3. Palæogeographic map of Tananwanian Age (Günz-Mindel Interglacial)

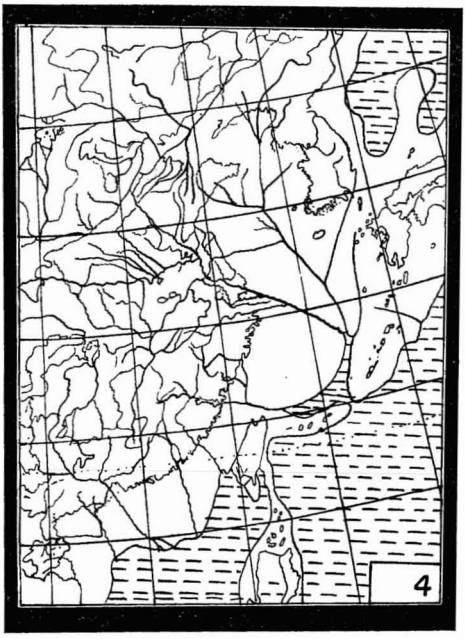

FIG. 4. Palæogeographic map of Tientzuhuan Age (Mindel Glacial)

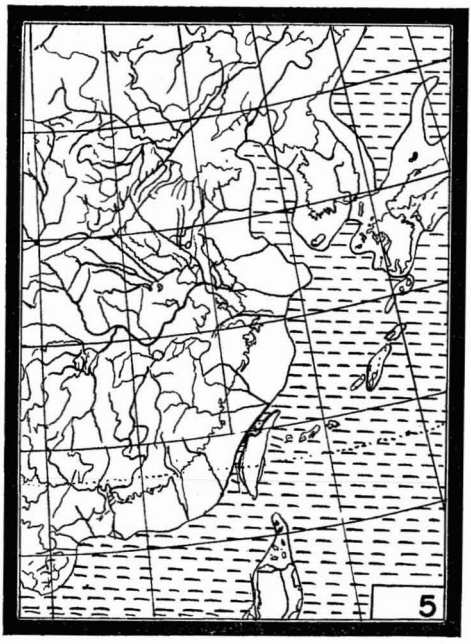

FIG. 5. Palæogeographic map of Tainanian Age (Mindel-Riss Interglacial?)

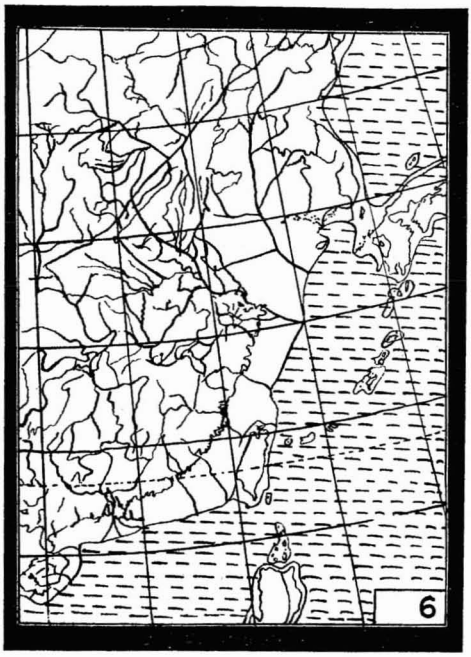

FIG. 6. Palæogeographic map between Tainanian and Milunian Ages (Riss Glacial?)

FIG. 7. Palæogeographic map of Early Milunian Age (Riss-Würm Interglacial?)

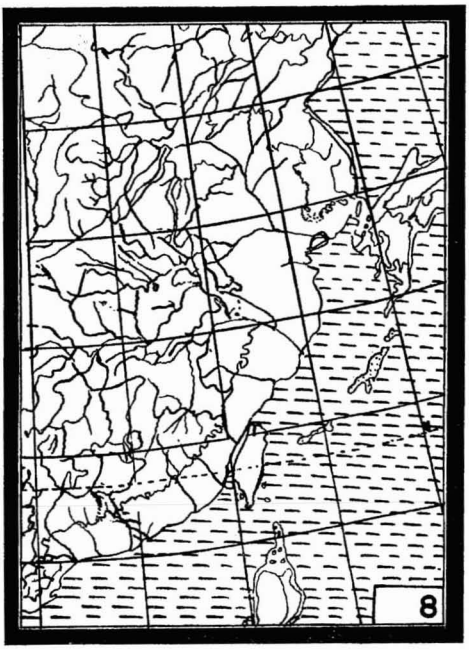

FIG. 8. Palæogeographic map of Middle or Upper Milunian Age (Würm Glacial, or Würm 2 stadium?)

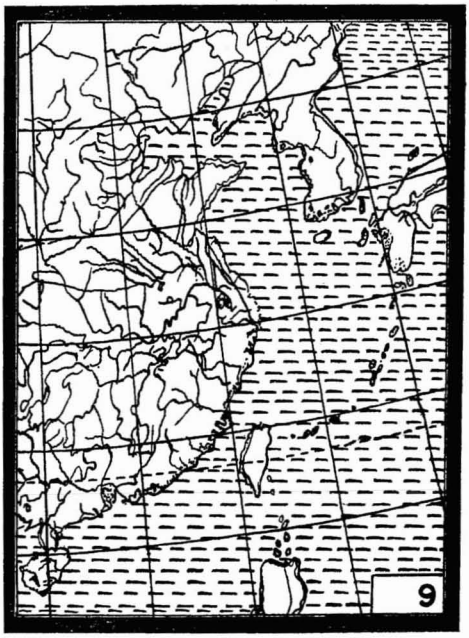

FIG. 9. Palæogeographic map of Hualienian Age (Post-glacial)

bringing the sea water again into the Taipei basin through the Kuantu pass. The Kunghsia shell-mound was submerged, and its inhabitants apparently moved onto higher land; the archæological site at Yüanshan shell-mound was apparently formed at this time. Another minor regression brought men down into the river valleys. A subsequent transgression, however, once more transformed the basin into a lacustrine region, larger in area than the previous Yüanshan shell-mound period. Fresh-water molluscs all but disappeared at this time, and salt-water and semi-fresh water species thrived. Another regression again extended the shoreline toward the sea, and such early sites as the Hsihsinchuangtzu shell-mound were formed in the low valleys along river banks. Early documents record that the last transgression took place in 1694 when an earthquake brought about the depression of a part of the basin and the entry of sea water. As far as can be judged, the surface of the basin at that time dropped not less than 3 metres. Since the 17th century the Taipei basin has been devoid of sea water.

In conclusion, the Quaternary Period in Taiwan was an age of rhythmic movements of transgressions and regressions of sea waters and fluctuations of shorelines. The scale of transgression decreased from one to the next, a fact which has made possible the preservation of many shell-mounds along the western coast of the island.

Orogenic Movements

Severe orogenic movements took place on Taiwan during the Quaternary Period in addition to fluctuations of sea levels. These have been grouped by the present author under the term, 'the Tungning orogenic cycle' (Lin 1957), which can be subdivided into the following phases:

Quaternary ages	*Orogenic phases*
Upper Holocene: Peipinian	Post-Hualien phase
	Hualien phase
Lower Holocene: Hualienian	
	T'aitung phase
Upper Pleistocene: Milunian	
	T'ainan phase
Upper Pleistocene: T'ainanian	
	T'aipei phase
Middle Pleistocene: Tientzuhuian	
Middle Pleistocene: Tananwanian	
Lower Pleistocene: T'ouk'oshanian	
Huoyenshanian Subage	P'englai phase
T'unghsiao Subage	
Tertiary—Pliocene	Pre-P'englai phase

The Pre-P'englai phase seems to have begun during the Neogene Subperiod. It is a period of small foldings, corresponding to the embryonic folding of the Tungning orogenic cycle. Because of this folding, a part of the Neogene subsystem emerged from the water and underwent erosional forces, providing sedimentary materials for the T'ouk'oshan group. For this reason gravels from the Neogene rocks are contained in the T'ouk'oshan group, the fossil Foraminiferas from which are thus also mixed with many secondarily derived fossils which were washed out of the Neogene Subsystem. Formed by this orogenic phase, the P'uli basin group is tectonic in origin, and in the basin have been deposited mud beds containing peats of the terrestrial T'unghsiaonian Subage and gravel beds of the Huoyenshanian Subage.

The P'englai phase witnessed the most violent orogenic actions in Taiwan's Quaternary history; these brought about the complex folds, simple folds, thrusts, overthrusts, and other formations in the western part of Taiwan, and completed the imbricated structure (Schuppen) of the Alishan range. The linear directions of the structures formed during this phase are completely parallel to the axis of Taiwan island. In the next phase, the T'aipei, blatts appeared which were nearly perpendicular to the linear direction of the P'englai phase structures, and block movements occurred on the island as a result of the formation of such transverse-fault groups, creating the Taipei basin among other structures. The T'ainan phase is characterized by north-south folds and high-angle faults. Formed during the T'ainan phase are the north-south-lying East Taiwan Great Fault scarp and the structural line of the T'aitung longitudinal valley; the Pianan tectonic line along the western edge of the Backbone ridge (including the Ch'aochou fault scarp); the Taichung tectonic basin; the Tatu-Pakua tilted block; the T'ainan tableland; and the Pescadores channel. The T'aitung phase is characterized by slow east-west folds and fault lines in the same directions. Formed during the T'aitung phase are the east-west fault in the middle part of eastern Taiwan and the slight fold in the T'ainanian and Milunian terraces along the eastern margins of the eastern coastal range. The forms of movement of the Hualien and the Post-Hualien phases largely reflect the geological structures of the Tertiary and the T'ouk'oshan group which was overlain by post-T'ouk'oshan deposits in the tablelands and coastal plains of West Taiwan.

Where the Tertiary and T'ouk'oshan group exhibit anticlinal structures, elongated terraces formed on the plain because of the orogenic movements during these last two phases; where the foundation rocks exhibit synclinal structures, depressions formed in the surface of the plain. During these phases, furthermore, ancient faults occasionally became reactivated. Some of the modern earthquake faults apparently reflect the formation of faults in the foundation rocks.

Volcanic Activities

The Quaternary of Taiwan was a period of violent volcanic activity. The basalt and the basaltic pyroclastics of the Pescadores were active from the T'ouk'oshanian Age, through the Tananwanian and Tientzuhuian Ages, up to the T'ainanian Age. The andesite and the andesitic pyroclastics of the Tat'un volcanic group at the northern end of Taiwan began to be active from the T'unghsiaonian Subage of

the T'ouk'oshanian Age; and evidence of their activities is seen throughout the Huoyenshanian Subage of the T'ouk'oshanian Age, the Tananwanian Age, the Tientzuhuian Age, and during the sedimentation of the Sungshan formation. The activity of dacite and dacitic pyroclastics of the Keelung volcanic group (including the Keelung islet) in the northeastern end of Taiwan began after the P'englai orogenic phase and lasted through the Tananwanian and Tientzuhuian Ages until after the T'aipei orogenic phase. The activity before the T'aipei phase was carried out by intrusion, and that after the T'aipei phase by eruption of the volcanic group.

The Quaternary volcanic activities on Taiwan also included those of basalt at Ts'aolingshan near Tahsi, and Chienshan near Hengch'un; and those of andesite and andesitic pyroclastics on the Agincort, Crag, Pinnacle, and Kuishan islets. They also included those of andesite and andesitic pyraclastics on all of Small Botel Tobago and a small part of Botel Tobago.

Pleistocene Man

During the several regressive periods of the Pleistocene, Taiwan was a part of the Chinese mainland and must have been near the Pacific coast. There were abundant forests and rich faunas and floras on the coastal plains and hills. Caves were available wherever limestones were present. It is probable that Taiwan in the Pleistocene was habitable, and, to my belief, it was then inhabited by men like those in the rest of South China.

The possibility that the animal assemblages driven by the cold climate during the Würm maxima into Taiwan from the north by way of the exposed shelf of the Formosa Strait has been mentioned by Kano (1954). During World War II Kano had the opportunity of examining several handaxe-like implements, found in gravel beds near Manila and Davao in the Philippines in association with stegoden bones, in the collection of H. O. Beyer of Manila, and made the remark that these implements closely resemble the palæoliths excavated by von Koenigswald in Java. On the basis of the conditions of preservation and making techniques, Kano concludes that these Philippine specimens can no doubt be called 'palæoliths'.

Studies in the geology of the ocean floors and ancient biological assemblages indicate that there must have been times during the Pleistocene when eastern Taiwan, Lutao, Botel Tobago, the Batan islands, the Babuyan islands, and Luzon were interconnected by land; or, at least, land bridges were available for their intercommunication. This route, in fact, must have been taken by the so-called Sino-Malayan fauna in their migrations from South China into Java by way of Taiwan, the Philippines, and Borneo. The discovery of the stegodon fauna on Taiwan further proves that Taiwan was in fact passed through by this fauna. No physical obstacle, therefore, stood in the way for Pleistocene Man to migrate from southern Chinese posts into the South Seas by way of Taiwan.

Y. Ino (1907) has reported two stone axes allegedly collected from a peat formation under Hut'ou hill at the northern end of the main island of the Pescadores. The peat formation in question is of Lower or Middle Pleistocene, and these two stone axes definitely belonged to Pleistocene Man if indeed they were found in

the ancient peat. Unfortunately these specimens are now lost and cannot be examined, and their actual provenance cannot be determined.

Limestone caves exist among late Palæozoic marble rocks in eastern Taiwan, among the coral limestones of the T'ouk'oshanian Age on the Hengch'un peninsula, near Takangshan in Kaohsiung prefecture and Shoushan in Kaohsiung city, and among the T'ainanian coral limestones near Fengshan in Kaohsiung prefecture and Hsiaoliuch'iu in P'ingtung prefecture. Unspecified animal bones have been reported from the caves near Fengshan. Evidence of occupation of Pleistocene Man on Taiwan may well be brought to light from sediments in such caves.

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