A Summary of Geological Observations in Taiwan from 1895 to 1948

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I. Preface

I have been requested by the editors of *Geology and Mineral Resources of the Far East* to summarize as briefly as possible, contributions to the field of geology in Taiwan until about the period of the rehabilitation of Japanese after the war. A number of geologists and geological engineers had worked in Taiwan from about 1895 until about 1945, when almost all the staffs of Government offices including University faculties, and those engaged in business sailed back home. However, a few Japanese professors remained in Taiwan to cooperate in various ways with the new faculty members of the National University. I and my wife remained, and I worked in the Department of Geology of the Faculty of Science until the latter part of 1949, working with the teaching faculty members, post-graduates and students, a few former students alumnai of mine, several graduates of Taihoku Imperial University, beside some newly appointed professors. Moreover, it happened that a few old friends were on the administrative staff of Taiwan National University.

The more than four and a half years as an honorary member of the National University was really a pleasant and fortunate aspect of my life. I was even able to do some scientific work either with the cooperation colleagues or by myself.

Our home life during our sojourn, of more than twenty years, was happy, but the last few years were especially impressive. We are thankful for the memorable association of friends and many others.

As mentioned at the outset, the editors wish to describe the extent of Japanese contributions toward geological enterprises in Taiwan. It seems more plausible, however, to describe how Japanese geologists and geological engineers laid foundation stones for modern earth science.

The edifice has been under construction for some time; we have to pay attention to it with great expectance.

What I have summed up may not include anything novel, however, I do not apologize to anyone because all these things have been put into an old wine skin.

II. General Geology and Topography

A. Introduction

It may be said that a Japanese scheme for systematic research on the geology of Taiwan came for the first time only around 1895–96. Until then records show that only a few European mining engineers had rather casually visited mineral localities here and there. Geological activities by Japanese in Taiwan were unexpectedly handicapped, however, because of the unaccustomed natural conditions, physiographical, climatological, and so forth, on the one hand, and of unstable civil conditions on the other.[1] Notwithstanding, many geologists devoted varying periods of time to exploring various parts of the island from time to time, chiefly in accordance with the research plan for East Asia of the Imperial Geological Survey,[2] the Tokyo Geographical Society and Tokyo Imperial University. In 1925 there was a Mining Section at the Bureau of Industry of the Government General of Taiwan with a geologist and a mining engineer forming the faculty. Then, in 1928, the Taihoku Imperial University was established, and included an Institute of Geology in the Faculty of Science and Agriculture (a few years later it was divided into the faculties of Science and Agriculture). Meanwhile the Mining Section was expanded somewhat and the number of geologists and mineralogists was increased from time to time to finally form the Geological Survey of Taiwan. Thus, this group and the University Geology Institute approached to each other in order to collaborate in every possible way on the geological sciences and techniques in Taiwan.

However, the famed 1:50,000 scale topographical maps of Japan published those days by the General Staff did not include all of those of Taiwan, particularly of mountain terrain, as they were delayed in preparation. As a result, the field work was carried out first in the hilly zones and flat lying plains regions, where coal and oil fields had been found buried; the exploitation of some metallic veins also seemed urgent. For this reason the field work was not carried out in regular order.[3]

Geologists during this period were engaged in various fields of the science. They worked hard during the war years though they had little luck in preparing reports or papers some of which contained significant data, or, much less luck in publishing them. Neither could most of them take materials with them when they were repatriated after the war. A number of unfinished manuscripts, photographs, charts, etc. were given up for lost. For this General Outline, many of those who were engaged for some time in geological work in Taiwan were asked by the Committee for written accounts of their respective observations and experiences, however, due to preoccupation with possible personal affairs and other activities not as many contributions as expected were received.

For my part, I stayed in Taiwan for four and a half years after the War as a professor of the National Taiwan University. I was able, more or less, to avail myself of information collected at random and edit a rather non-professional essay entitled "An Outline of the Geology and Geography of Taiwan" (1943).[4] This was written at the request of a certain Chinese professor who came from mainland China after the War. Up to this time *Taiwan Tigaku Kizi* (Geological News of Taiwan) was published occasionally by the former University Geological Institute. I had access to a few other publications issued by associates. Most of the material for this General Outline compiled in Tokyo a few years after my return home in 1949 was taken from these sources. Although this material was far from being satifactory for the purpose mentioned it was supplemented with my personal experiences in Taiwan. Reports on the areas of mineral resources have not been covered and will be done by others who are more knowledgeable about the subject.

As the history of geological exploration in Taiwan by the Japanese is not as so long as that of the Chinese mainland, and at the same time as the size of the area concerned was rather limited, not to speak of limits in planning, the results of studies are neither conspicuous, nor much to boast about. When geologists started their activities earnest around 1915, geology from the scientific had also of begun to seriously consider careful observations of the faces of nature. Therefore, if we record everything, there will be a vast amount of material including hitherto unfamiliar phenomena, because of unfamiliarity with territorial conditions. With regard to exogenetic processes we had to pay heed especially to weathering, river erosion and transportation, sedimentation, landslips, and thermal springs (ground water).[5] Concerning endogenetic processes, seismic activities are important in Taiwan, there having been severe and often destructive earthquakes every four or five years.[64] In the field of paleontology, beside numerous molluscan fossils of different ages, there are unexpectedly frequent mammalian remains chiefly from Pleistocene formations; foraminifers, brachiopods, and echinoderms are of significance, especially for biogeography, and as materials for studying the problems of "actuo-paleontology" and also the "actuo-geology."

A comment on III is necessary here. III is based largely on an article by HAYASAKA, LIN and YEN entitled "An outline and some problems of the Stratigraphy of Taiwan."[6] Some changes were in contents, however, to take into consideration papers by the late K. TAN on the Eocene and Paleogene faunas,[7] a note by YEN on the younger Paleozoic fossils[8] and a report by LIN on a Jurassic faunule discovered deep beneath the coal- and oil-bearing Neogene formation by LIN.[9] These papers and the theories derived from them have provided remarkable additions to our knowledge of stratigraphy, historical geology, structural and economic geology of Taiwan.

B. PHYSICAL GEOGRAPHY

A conspicuous continental shelf embraces the southeastern part of the east coast of China. On its margin the mountainous island Taiwan rises abruptly above the level of the sea. The Formosa strait or channel which is barely 100 m deep is located between the continent and the island. The Pescadores islands are located and consist of more than 70 large and small islets and rocks, that are considered as dissected remnants of an extended basalt mesa. The real continental margin of this part of eastern Asia coincides with the eastern border of the island of Taiwan which very abruptly descends to the abyss of the western Pacific.

Excluding the Pescadores and several other dependent islands like Ka-sho-to; Ko-to-sho and smaller islets, the main island of Taiwan has a somewhat fusiform outline in plan with the longitudinal axis extending roughly north-south. Strictly speaking, however, this longitudinal axis forms an arc with its convexity facing westward: the northernmost part trends almost north-northeast to east and the southern major part extends almost due south on slightly by south-east.

As has been recognized by geographers and geologists, the insular festoon of eastern Asia is composed of several arcuate islands like the Kuriles, north-east and south-west Japan, and the Ryukyu arcs. All of these arcs face the Pacific with their convex sides. This was pointed out a long time ago, for instance, by V. RICHTHOFEN,[10] as a characteristics feature of the geomorphology of eastern Asia. The northern extremity of Taiwan turns toward the east, and points to the western end of the Ryukyu island arc. The geological relation between these two arcs must be an interesting but very perplexing problem. As is well known, V. RICHTHOFEN also propounded a theory long ago, but the modern theories in structural and morphological geology may not conform to it.

Be that as it may, the maritime mountain range of southern China, the Hsien-Hsha-Ling, appears to assume an arcuate trend with its concavity facing eastward: it is as if a concentric curve is drawn by Taiwan, though it may be merely coincidental.

Another point probably worthy of note regarding the physical geography of Taiwan is its very simple shoreline. This may have been due, as a whole, to the very recent relative upheaval of the island. Yet, it is discernible that the very steep, precipitous cliff along the eastern coast is naturally much simpler than those on the western, marshy shore with a broad watt in front. The total length of the shoreline of the main island measures only about 1,144 km, while the total area occupies 35,970 sq. km: in other words, the average length of shoreline per sq. km is 0.032 km. On the other hand the Pescadores Islands have the total area of about 79 sq. km. at low tide, with the average length of shoreline per sq. km. being as large as 1.45 km.

C. SALIENT TOPOGRAPHICAL FEATURES

The topographical feature which seems most significant is the fact that a lofty mountain system runs almost lengthwise through this small island; it is the Taiwan Mountain System which is also important in the consideration of the geology.

The Taiwan Mountain System consists of several ranges, long and short, almost parallel to each other. All these collectively form a high plateau-like topography comprizing more than a dozen high peaks over 3,000 m. Of the parallel ranges the one which may be called cardinal rises immediately south of the triangular plain of Giran and Rato, with an almost circular cove, called Suo in the southeast corner of the plain; it is a part of Taihoku Prefecture. It extends south-westward for some distance, and quite abruptly increases in altitude to culminate in the Nanko-tai-zan (3,535 m). Here, the range turns south-south-west, and begins to show a tendency toward realization of the commanding position of the Axial or the Backbone Range; the latter, with some slight, irregular bends, extends southward, finally reaching close to the southern end of the island. Among the prominent peaks that follow toward south are the Chuo-Senzan (3,412 m), the Anto-Gunzan (3,087 m), the Kan-zan (3,667 m), the Sho-Kuan-zan (3,254 m), the Pinan-Shuzan (3,305 m) and the Daibu-san (3,262 m).

An apparently subsidiary range extends north-northeast from the Nanko-Tai-Zan, and ends in the promontory of Samtiao Point in NE. Generally speaking, deep gorges are carved between these ranges: their upper courses take almost the trend of the ranges, turning to a more or less westerly direction in the middle course, and finally, almost due west, down to the Japan Sea.

Due to this topography there are different landscapes that represent the very young history of the formation of the island.

Some singular features of mountain passes, intermountain basins, large and small, river terraces and the like, are formed.

Another subsidiary range extending southwestward carries the peaks of Tsugi-taka-yama or Setsuzan (3,931 m), etc. This short range is called the Tsugitaka Range. Between the Axial Range and the Tsugitaka Range, almost at the latitude of Nanko-Daizan, in the former, and the Tsugitaka Peak of the latter there is a high mountain pass, popularly known as the Pianan Saddle, dividing the very steep, and deep gorges of the Daikokei, running about south-south-east, and the Dai-Dakusui-kei, flowing almost north-northeast, and terminating in the delta of the Giran and the Rato rivers formed by sediments carried down by these rivers. Thus, the courses of these two rivers are nearly on a straight line; this most likely suggests the existence of a sort of crustal disruption zone possibly on a grand scale. The southern slope of the Saddle, that is, of the Daiko valley presents an unusual topographical feature resembling a shallow lake basin filled with sediments of clays, and gravel and the like; these lake deposits have been dissected by the headstream waters of the Daiko-kei, exposing the profiles of the sediments. The northern Dakusui-kei gorge, is roughly about 40 km from the mouth to the Pianan Saddle. South of the Pianan Saddle, about 20 km southward, the Daikokei gorge turns westward and across the midland zone, middle part of the island flows down into the sea as stated above. The behavior of the courses of the rivers on the western slope of the Axial Range is in general similar to that of the Daikokei. Most of the river valleys extend lengthwise in their upper courses, parallel with the length of the island, turning southwest or due west in their mid-lower, or lower courses.

Mountain passes somewhat similar to the Pianan Saddle are not unfamiliar in Taiwan. The Tahtaka Saddle (2,250 m), and the Hattsu-kan (2,800 m), east of Arisan, are examples; the former is situated between Niitaka (3,950 m) and the

Arisan ranges, and the latter is in the west of the Niitaka. The valleys to the north and south of both passes run almost west-east, each coinciding with the geological structures observed in these region.

The loftiest peak Niitaka-yama, i.e. Yu-shan, consisting in reality of several peaks of varying heights arranged more or less in a north-south direction. This group is situated to the west of the Axial or Backbone Range beyond the Hattsukan mountain pass. Its southern extention rather abruptly lowers down to the plains of Heito and Takao.

A distant view the Niitaka range gives the physiography of a plateau, conforming to the general appearance of the whole island in a silhouette, so to say, this seems to be significant in consideration of the geology and geohistory of Taiwan.

The Arisan range is located to the west of the Niitaka-yama beyond the Tahtaka Saddle and extends in a north-south direction. The range is only 1,000 to 2,000 m high as a whole, the Arisan itself forming its loftiest peak.

Thus far an outline of the topographical features of the mountainous region has been presented. Some distance to the west beyond the Arisan is a zone of hilly lands several hundred meters in average height, more or less sposmodically developed in a roughly north-south direction. To the north this is traced in part on the north-west slope of Tsugitaka-yama. While the mountainous region is built up, chiefly of the Paleogene slaty sediments, this hilly zone is occupied by the Neogene and the younger formations as far as is known on the surface. Further westwards is a flat lowland of Diluvial and Aluvial deposits. The slaty Paleogene formations yield relatively numerous fossils though not many of them are excellently preserved; there are molluscs, echinoids and the so-called higher foraminifers among the invertebrates, and some fragmentary remains of terrestrial plant leaves. The Neogene formations are much more richly fossiliferous, especially in certain localities. Beside the Invertebrates, as for instance, foraminifers, molluscs, echinoids, bryozoans, brachiopods and a few insects, several vertebrate jaws, teeth and bones of mammals and a few reptils also have been discovered in several localities. These fossils have been studied by several paleontologists, most of whom have published their works; among these fossils a major part belongs to the Pleistocene.

Taking all these fossils into consideration, as well as the observations on the sediments, it is evident that all the Cenozoic sediments and the fossils therein indicate a shallow sea environment during the Tertiary and Quaternary ages; the present-day physical environment is very similar and looks as if represents the last phase of the Geosynclinal stage.

The last zone of West Taiwan is occupied by the Alluvial plain which continues to the flat Wattenmeer or the shoal sea. This muddy flat in the middle of Taiwan is several kilometers wide, and there are examples of several paddy rice fields made in the historical ages from such shoal flats, around Tainan and northward. This is considered to have been due, at least in part, to the constant uprising of the island as a whole, which might have been active even during fairly recent historical period.

Turning to the eastern side of the island, the very steep and ruggedly precipitous cliff hanging down into the deep, blue Pacific are immediately noticeable. The Axial Range, as seen in plan, divides the island into two unequal halves, the eastern half being about half as wide as the western. Consequently, there are longer rivers with much more water in western Taiwan than in eastern Taiwan. The great rivers of western Taiwan, most of which carve deep gorges, accompany graceful river terraces in the upper and middle courses, and spred into wide agricultural grounds of the coast in the middle or lower course. The valleys on the steep slope of the Axial Range on the eastern side are naturally much shorter, and the water, mostly flowing deep in the bottom of the gorges is characterized by magnificent incised meanders.

The development and distribution of the Alluvial plains are commanded by the topographical characteristics sketched above. The most extensively of such plains is the Heito-Takao; the western coastal part continues northward with the Tainan coastal plain. Farther northward, beyond Tainan, there are a few, less conspicuous but not discontinuous coastal plains of West Taiwan.

Inside this stretch of the West Taiwan shore plains is a series of narrow and low hills of Neogene and Pleistocene deposits, arranged roughly longitudinally. Within or inside this low series of hills are several basins equally arranged in an almost north-south directions. The most conspicuous among them is the Taichu plains. The Taihoku basin in the north is of structural origin surrounded by faults, and it is evident that it was once filled with water, as is evidenced by remains of certain fresh-water shells and debris of terrestrial plants.

In eastern Taiwan, the plains are still more limited in expanse. In the north the Dakusui-kei delta plain where the Giran and Rato are found local towns are conspicuous.

From the south-eastern corner of the Giran-Rato delta, that is from about the small, almost circular cove of Suo, the coast extending south-southeast traverses the trend of the Axial Range forming very steep, hanging cliffs until it reaches the coastal plain of Karenko. Beside a few, small deltaic estuary plains along these hanging cliffs, a plain appears around the town of Karenko which is a metropolis of eastern Taiwan. As a matter of fact, the so-called Karenko coastal plain is somewhat more complicated than it first appears to be, both in extension and also in formation. It may be said that it was composed of several deltaic deposits combined, the northernmost being the one formed at the mouth of the Takkiri-kei. The plain is very narrow until we get to the Karenko, where it gets wider because the debris seem to have been brought forth from at least more than one source. A part came from the eastern slope of the Backbone Range, the other was transported from a wide valley occupying the broad depressed zone of the Backbone Range and from what is called the Taito Coastal Range; it is the so-called Taito Longitudinal Valley, about 130 km long, and about 10 kg wide. At about a little less than a third of the length from north of this longitudinal valley a low but apparent watershed is located. The waters of the three relatively rich rivers from the Axial Range flow down into the longitudinal valley, and reach its eastern valley wall, to turn to north toward Karenko. It is another source of supply of the deltaic deposits of Karenko Plain. Thus, it is possible that the formation of the plains around Karenko may have been complicated. The southern two-thirds of the longitudinal valley is similar pattern to the northern one-third, and another low watershed comparable with the first is located about 60 km south of it. The river waters of this section of the longitudinal valley drain into the Pacific through the Shukoran traversing the Taito Coastal Range, cut by the conspicuous loops of the incised meanders. This and those of the eastern slope of the Axial Range suggest a rather sudden upward movement of the island of the most recent date, because the Neogene formation is contained in it. In the rest of the Longitudinal Valley the waters flow southward, to Taito, and also close to the eastern coast of the Taito Coastal Range. The bottom of the Longitudinal Valley is by no means flat, but of different types of deposits are found here and there, these sediments being of different thicknesses, forming river terraces here and there.

The maximum altitude of the Taito Coastal Range is 1,682 m, and the maximum width is not quite 20 km. It is composed of Tertiary sediments accompanying some andesites, agglomerates and tuffs, as well as occasional exposures of serpentinite.

The western side of the Taito Longitudinal Valley, namely, the steep western slope of the Axial Range has been assumed to be a dislocation of a grand scale. The topographical features seem to favour this idea. The famous steep cliff between Suo and Karenko runs in a straight line against the western cliff of the Taito Longitudinal Valley.[11)] Its eastern wall also is regarded by geologist as a dislocation. Thus, the Taito Longitudinal Valley is most likely a depression formed by faults, if not a graben.

In consequence of the asymmetry of topography, the water system also is asymmetrical in various ways. The rivers in eastern Taiwan have their sources everywhere in the backbone range. At certain top stream regions, the water flows in the flattish and comparatively shallow extensive basins formed high up on the mountain range: from there the collected waters flow down along cardinal streams through a valley or valleys. A typical example is the plateau surface northwest of Karenko. In certain cases, small marshes or swamps supply drinking water to mountaineers.[12)]

In Taiwan lakes are not common. The most famous is the Jitsu-Getsu-Tan (Sun-Moon-Lake after the Western style of appelation), which is located in the hills about 190 m high. It is a rather shallow lake occupying almost the center of the whole island, and the bottom is 720 m above sea level. In this region a zone of dislocation seems to longitudinally run throughout, and a longitudinal series of basins of different sizes, filled with water, were produced, possibly at more or less different altitude. Among these lake basins the Jitsu-Getsu-Tan might have been the highest in position, or, the region as a whole might have been up-warted with the Jitsu-Getsu-Tan at the center, so that they were drained off, the remoter from the center the faster, the Jitsu-Getsu-Tan alone remaining with water now.[13)]

The Jitsu-Getsu-Tan has been made use of by the Taiwan Electric Company as an electric power reservoir for many years, and has been deepened and enlarged to a great extent. Its original area was 4.4 sq. km.

A seismogenetic lake much larger than Jitsu-Getsu-Tan was formed in December of 1941 by damming up the Seisui-kei with the debris shaken off by severe earthquakes from the steep walls of the river. The Seisuikei, which is a tributary flowing down chiefly through sandstone formations, to the master river Dakusui-kei, of which the major part of the course runs through a terrain of black slate. The dammed-up lake was reported to be barely 6.6 km in extension, and almost 55 m in maximum depth. In reality this was much larger than the Jitsu-Getsu-Tan, but in a few years the seismo-genetic dam collapsed naturally, inflicting some damage to the farmlands below.

Taiwan's next important lake is man-made. In this case the river Kandenkei which is richly supplied by numerous tributaries in the lower Pliocene terrain northeast of Tainan City, was dammed up in its lower reaches. This lake was very seriously planned and brought into realization because of the problem of irrigation for agriculture land in these areas which had been considered by the Government for many years. Its total water surface is barely 9 sq. km.

Beside the lakes in the alpine regions, there are a number of small ponds and marshes that are well considered to have genetic connections with glacial or freezing phenomena during a late geological age, possibly at about the late Pleistocene. It is assumed that this period was one when the whole island rose hundreds or perhaps a thousand meters following the subsidence of the island, on the basis of the submarine canyon south of Takao, as well as the step terraces surrounding the Daiton-zan, an isolated volcanic dome originally a submarine volcano, situated along the shore north of Taihoku. The numerous river terraces on the sides of rivers were traced, and it was discovered by Y. Tomita[14)] that there are roughly corresponding steps in all the valleys. This also may involve some sequence with the phenomena referred to above.

In the southwestern plains region, we find lagoons formed along shore. The careful observations will show various evidence important for the study of Recent geological history. Especially, in and around Anping and Tainan regions some such finding may throw some light on the connections also with the historical consequences.

III. Stratigraphy and Geological History

A. A Historical Sketch of the Stratigraphy and Geology of Taiwan observed since the end of the Nineteenth Century

Since about the turn of the century, geologists had been engaged in stratigraphical research in particular areas of Taiwan, according to specific purposes. However, for the compiling of a general geology or stratigraphy the material remained far from satisfactory although Y. Ishii[15] had prepared a Reconnaissance Geological and Mineral Resources Map as early as 1897 which, however, did not appear to be of much practical value. The Map of Topography, Geology and Mineral Resources of Taiwan, 1:300,000, compiled by Y. Deguchi[16] in collaboration with two mining engineers, was published by the Government General of Taiwan in 1912. It was the result of personal efforts and experiences over a period of several years. This map and the explanatory text actually laid the foundation for further research.

Between 1898 and 1917 several geologists and mining engineers, besides Ishii and Deguchi, worked for the Government. As a matter of fact, Deguchi himself studied the geology of the Daiton[17] volcano north of Taihoku (1912), and his paper on the geology of the Hoko (Pescadores) Islands appeared in the same year. Shorter accounts on the same Island were published by Y. Saito[18] as early as 1897. Deguchi also visited the Taito Coastal Range together with G. Hosoya, a mining engineer, and presented a report to the Governor General. Some reports on the coal and oil fields as well as on certain metal mines, mostly in the northern part, were also presented.

In the meantime, Y. Ichikawa completed geological exploitation works in Taiwan. He and H. Takahashi, a mining expert, were teamed for several years after. He was fortunate because a lot of accumulated information and material were available for reference.

With the new information a new edition of the 1:300,000 Geological Map with accompanying text entitled "Explanatory Statements of the Geology and Mineral Resources of Taiwan (Formosa)[19] was compiled by Ichikawa and Takahashi. For some years this publication remained a very useful guide for everyone concerned with the geological sciences of Taiwan.

It is noteworthy that in the explanatory text, the geological formations were divided into Tertiary and Pre-Tertiary. For the present the Tertiary will not be touched.

Some comments on Pre-Tertiary will be made. Besides a group of igneous rocks, five other groups are distinguished: 1. Gneiss group; 2. Crystalline limestone; 3. Crystalline schists; 4. Lower Slate formation; 5. Upper Slate formation. The first three groups are not clearly distinguished, but rather different kinds of rocks are often found intricately blended so that Ichikawa and Takahashi were not able to discover any fossils in them. The Lower and the Upper Slate formations appeared in general continuous, but were unconformable in certain places. The Lower Slate formation is often found gradually changed into chlorite and graphite schists in the east. The Lower Slate Formation consisted of alternating beds of slate, graywacke and phyllite, and widely occupied the Axial Range area. It is here that M. YOKOYAMA[20)] once recognized *Macrodon* ?, *Cucullaea* ?, *Myophoria* ?, and *Schizodus* ? in the neighborhood of Niitaka-yama, and assumed that they could possibly point to upper Paleozoic and Triassic in age. The Upper Slate Formation continues to the west of the Lower Slate Formation, and consists of black slate and graywacke below and black slate and sandstone above. The Tertiary formations extend westward.

A (Scale 1:50,000)

Sheet No.	Name	Date	Author
9.	Taihoku	1930	Y. ICHIKAWA
17.	Chikutō	〃	〃
13.	Tōen	〃	〃
18.	Ritōzan	1931	Z. OOE
5.	Daitōzan	1932	OOE & M. OGASAWARA
4.	Tansui	〃	〃
14.	Shinten	〃	Y. ICHIKAWA
11.	Kyūkō	〃	T. MAKIYAMA
7.	Oosono	〃	〃
8.	Kannonzan	1933	〃
12.	Chūreki	1934	〃
16.	Shinchiku	〃	〃
21.	Hakushaton	〃	〃
15.	Tōi	〃	Y. ICHIKAWA
35.	Tōsei	1935	K. TORII
27.	Taikō	1936	M. OGASAWARA
20.	Ratō	〃	M. USAMI
20.	Giran	〃	〃
12.	Hōkasho	1937	T. KIMURA & R. MATSUMOTO

B (Scale 1:100,000)

Sheet No.	Name	Date	Author
2.	Dainanō	1933	M. OGASAWARA
4.	Kenkai	1936	〃
9.	Toyohama	1939	M. USAMI
6.	Karenkō	〃	〃
13.	Taitō	〃	Z. OOE
16.	Daibusan	1940	M. USAMI

In 1927, the Imperial Japanese Navy published the "Report of the Geological Reconnaissance of the Oilfields of Taiwan," by Y. OOINOUE et. al. The field work covered all the known and promising areas,[21] as a matter of course, outside the alpine regions. Generalized geological maps were of 1:200,000 scale.

It was only in 1930 that the Geological Survey of Taiwan published the first of their Geological Sheets.[22] The Survey belonged to the Mining Section of the Bureau of Productive Industries of Taiwan. Naturally the plan was to produce sheets covering the whole island, but it was unfortunately abandoned in 1940 after a total of 25 had been published. Nineteen of the 25, including the northwestern part, are in a 1:50,000 scale; the other six of the eastern mountainous region are in a 1:100,000 scale.

The Geological Sheets of Taiwan published by the Government General of Taiwan[22] are listed below.

Almost simultaneously the organization of the Geological Survey was improved to some extent in order to press forward with the exploitation of petroleum reserves, and a few geologists were invited for this purpose. During the period from 1931 to 1938 a number of geological reports, especially elaborate in stratigraphical and structural features were published under a dozen titles, each with the name of an oil field or two, but often including the records of other nearby oil fields. The oil fields are listed below according to the order of their locations.[23]

Reports on the Oilfields of Taiwan by the Bureau of Productive Industries of Taiwan

Oilfield and Location	Date	Geologists
Byōritsu & Chikutō, Shichiku Prefecture	1932	K. TORII
Kagi, Tainan Prefecture	1931	H. ROKKAKU
Shika, 〃	1932	K. TORII
Tamai, 〃	1934	H. ROKKAKU
		T. MAKIYAMA
Kizan, Southwestern part, Takao Prefecture		K. YOSHIDA
Kizan, 〃	1933	K. TORII
Kōshun 〃	1934	ROKKAKU & MAKIYAMA
Koume, Tainan Prefecture	1935	YOSHIDA
Senzanko, Taihoku Prefecture	〃	TORII
Sanshikyaku, 〃	1938	K. TAN
Seisuiko, 〃	〃	H. HISAZUMI
Kokusei, Taichu Prefecture	〃	Z. OOE

In the meantime, members of the Taihoku Imperial University began their search. Their activities covered almost the whole island and included several dependent islets. In the domain of minerals and rocks the late Prof. T. ICHIMURA[24] took the lead, with the assistance and cooperation of a few senior and postgraduate students. Along this line of research, however, ICHIKAWA[25] and HATTORI *et* *al*[26] contributed to some extent. As to the paleontological works quite a lot had been carried out by members of the Tohoku Imperial University,[27] Sendai, such as S. NOMURA (Molluscs), S. HANZAWA (Foraminifera), and H. YABE (corals). Besides, M. YOKOYAMA also had already published several papers describing the Tertiary molluscs collected chiefly by geologists who had engaged in field works in different oilfields.

Fossil molluscs were studied also by members of the Taihoku Imperial University, including K. TAN, C. C. RIN, and K. ISHIZAKI. Regarding the Tertiary molluscs, the scheme had been to collect as many species and as many individuals, not only of the fossil shells but also of the Recent forms, so as to be able to make clear the real faunal relations between the fossil and actual forms in this part of the world. In other words, so-called "actuo-paleontological" data was sought with respect to molluscs so abundant in this region. For this purpose S. KANEKO and T. KURODA provided excellent service, by successfully collecting numerous specimens, and publishing excellent catalogues and papers.

Among the most noteworthy publications of this period was "A List of Japanese Neogene, Pleistocene and Recent Foraminifera, excluding Orbitoididae, Re-

Table 1. A General Stratigraphical Scheme of Taiwan by HAYASAKA, LIN and YEN (1947).

	North	South	Eastern coastal range
Holocene	River and Shore terraces lake deposits, etc. Older terraces and fans	River and Shore terraces Raised reefs Older terraces and reef Limestone terraces	River and Shore terraces Older terraces
Pleistocene	Faulting——Titling——Erosion		
	Tableland Gravel	Older Reef Limestone	Older Reef Limestone
	Folding, Thrusting, Upheaval, Diaton Volcanic activity, Erosion		
Neogene	Tōkazan Group	Syokkōzan Conglomerate Tsūsyō Sandstone	Pinanzan Conglomerate
	Byōritsu Group	Takuran Sandstone and Shale Kinsui Shale	Sandstone and shale
	Kaizan Group	Upper Kaizan beds Middle Kaizan beds Lower Kaizan beds	Sandstone and shale Agglomerate and tuffite
Palaeogene / Basic & Acidic Intrusions	Regional Metamorphism		?
	Slate Formation——?——Metamorphic Complex		Basic Intrusives

corded up to 1938" by K. ISHIZAKI.[28] This was the result of his strenuous efforts to build a base on which he expected to develop his field of study. The list was published in the *Taiwan Tigaku Kizi*, vols. X and XI (1939 and 40), 182 pp. including 21 pages of Index.

The late K. ISHIZAKI left many papers, however, on the Cenozoic smaller foraminifers from Taiwan; one of the important works was "An Index to Formosan Stratigraphy", 1942.[29] The promiscuity of the stratigraphical terms used in the geology of Taiwan had troubled geologist for a long time. Therefore this convenient Index was warmly received. The validity of this list is expected to last for a long, and be enlarged and revised as time passes. ISHIZAKI picked up over 160 names from 45 articles published by about 20 authors. This list was published in Nos. 220–226 (January to July, 1942) of the Transactions of the Natural History Society of Formosa, vol. XXXII.

Beside these rather routine type of research, various works, often of particular significance, were taken up by geologists either of the Geological Survey or of the University faculty. Graduation theses by University students were also available. All of this helped to increase our knowledge greatly during these years. However, as is suggested by the compilation of the Index, it is difficult to classify, and wear some to recapitulate the correlation. Thus, for convenience's sake, a brief correlation table was compiled in a somewhat generalized form with slight improvements by HAYASAKA, LIN and YEN, in 1947. As I stayed in Taiwan several years after the war I had the privilege of joining in this project, working together with them and other colleagues. The Table given below is brief, but is slightly more than a mere order of succession of formations. We endeavored also to involve more manifest geological events recognized up to that period.

B. THE METAMORPHIC COMPLEX

The correlation table (Table 1) mentioned above is based on previously-mentioned paper "An Outline and some Problems of the Stratigraphy of Taiwan," which was for some years an expedient reference. The explanations given by basal Metamorphic Complex and Slate Formation, as well as other formations, will be recapitulated in the essence.

The Metamorphosed Complex[30] is composed of a group of crystalline rocks occupying the eastern wing of the Backbone or Axial Range; rocks distinguished are paragneiss, sericite-graphite schist, chlorite schist, graphite schist, phyllite, conglomerate, etc. among the sedimentaries. Of the rocks of igneous origin, granite, granite-gneiss, hornblende-mica-quartz schist, and amphibolite are known to occur as injections into the schistose rocks, being metamorphosed together. The dykes of pegmatite, quartz and lamprophyres penetrating them are characteristically free from schistosity.

To the west this Metamorphic Complex becomes gradually weaker in metamorphic alteration. Approaching the crest line of the Taiwan Range the chlorite and graphite schists are found in thin alternation in many places in association with crystalline limestone on the one hand, and black clay slate on the other. Farther west the black clay slates gradually become dominant. In the mountain range to the west of Karenko some Eocene foraminifers, such as *Camerina, Discocyclina* and the like were discovered in the limestone bed in the transitional zone of the Metamorphic and the Slate Formations.[31] Similar Eocene foraminifers were found in the thin limestone in the black slate farther west, as well as in the north and south of the Axial Range in several places. For some time K. TAN indulged in collecting such foraminifers as well as, with almost equal frequency, molluscan shells. Fossil occurrences like these seem to have suggested to some people that the two groups of formations referred to might be intimately related to each other.

In the Metamorphic Complex the Xenoliths of quartzite conglomerate are found occasionally, T. ICHIMURA[32] who examined them microscopically was of opinion that the grade of metamorphism of the conglomerate is different from and stronger than the matrix. His assumption is that there was a period of metamorphic process before the formation of the Metamorphic Complex itself, and also that the quartzite conglomerate block might have originated somewhere beyond the Formosa Strait, on the continent.

In the meantime, T. P. YEN, now of the Geological Survey of China and two of his associates happened to discover some fragmentary specimens of fusulinid foraminifers during field works in the Metamorphic Complex region. The fossils were preserved in the Crystalline limestones, and were collected in the exposures north of Hualien, at three localities, namely, Tungai, Nantzu, and Kussu. Although the fossils in thin slides are only scarcely recognizable by trained eyes, this discovery was really a memorable event in the history of the geology of Taiwan. In fact something like the features of such fossils were alluded to by T. ICHIMURA[33] and K. TAN[34] a few years ago; they recognized some questionable fragments of a coral-like enclosure which were hardly possible to identify from the exposures of the same crystalline limestone in the same region.

Following a paper written in 1951, YEN wrote another paper in 1953,[35] in which not only the localities of fossils were increased and the distribution of the fossils extended but also the paleontological examination of the fossils had been recorded. The fossils were examined by Prof. M. L. THOMPSON of the University of Wisconsin who said that the fusulinids are *Schwagerina* ? sp., *Neoschwagerina* ? sp., and *Parafusulina* ? sp. Besides, in the opinion of Prof. TIN YING H. MA of the National Taiwan University, a tabulate coral was found by YEN in the same metamorphosed limestone: it is a species allied to *Waagenophyllum,* an important genus in the Permian of the Indo-Pacific region.

In 1960, another article by YEN appeared on the Metamorphic Complex, entitled "A Stratigraphical Study of the Tananao Schist in North Taiwan."[36] In this study the author endeavored to further scrutinize the stratigraphy of the Metamorphic Complex based on the knowledge of their petrography and petrology, supported by the petrofabric and the geology of the region. He descriminated the Tananao Group and the Tananao Schist: the former is the original Paleozoic sediments, while the latter is the metamorphic product of the former. The Tananao Schist is tentatively classified as follows, numbered from top to bottom:

4) Yuli formation (ca. 2,000 m): Triassic (?) to Up. Permian:
   Coarse-grained sandstones dominant, accompanying shale beds, basic tuff beds and serpentinites.

3) Tailuko formation:
   a. Tungaw facies (ca. 2,100 m): sandstones, shales, basic lavas and tuffs, limestones (with fusuline fossils)
   b. Tachinshui facies (1,200–1,800 m): mainly limestones with some of tuffs and cherts (with *Waagenophylum*, and larger forms of fusulinids above).

2) Kanagan formation (ca. 800 m): arkose of coarse-grained sandstones, and partly sandstones, shales, and limestones, metamorphosed to paragneiss, locally original sediments.

1) Sanchui formation:
   a. Gong facies (500–700 m): sandstones, shales, basic tuffs and limestones dominating. Permian and/or Carboniferous
   b. Raushi facies (500–800 m): Limestone dominant, a little of basic cherts and tuffs.

Each of the stratigraphical units are minutely described and compared with the stratigraphical sequence of the Yoshinogawa group of Shikoku, Japan, by Prof. J. Kojima of Hiroshima University, Japan. Yen points out that in the rock sequences, lithic characters and grades of metamorphism in the Tananao Schist and the Yoshinogawa Group are very akin to each other, except for the very rich development of the limestone in the former; that is, the former is quite like the Sanbagawa Group of Japan.

In a paper "A Geologic Consideration on the Taitung Valley, Eastern Taiwan" (1967),[37] Yen explains the geological structure on the basis of own research, and recorded the discovery of a thrust fault around in the southern part Chulu area, and an unconformity and/or a fault at Fuli, both in the Valley almost buried under the thick Quaternary sediments that fills the Valley.

What is of particular interest here is, the Yuli formation forming the western side of the Valley, that is, the eastern slope of the Axial Range. It forms the upper division of the Tananao Schist as referred to above. In the southern part of the Valley, especially between the north of Luyen and the neighborhood, the eastern slope of the Axial Range is occupied by a slate or phyllite formation, which is questionably assessed at Paleogene by Yen.

The Yuli formation is assumed to range from the Permian to the Triassic. Possibly the last mentioned bed of slate or phyllite may be conjectured to represent the Triassic part of the Yuli formation. Were this inferential conception allowed, could it not be expected that this phyllite part forms a lower horizon of the Slate Formation upon which the succeeding Mesozoic formations follow?

Turning back to the Tananao Schist, the very thick limestone of its middle part yielding fusulinids and a few other fossils of the Permian age is reminiscent of similar thick limestone formations in Japan which contain hosts of fossils, representing different zonal assemblages ranging from Carboniferous to Permian. Although the Tananao fauna is not very lucid so far, there is no reason to give up the hope for future discoveries both in the mode of preservation and in the kind of fossil organisms, as well as of different fossiliferous horizons of the Paleozoic. This limestone and possibly also the less conspicuous ones in the other parts of the rock complex look promising in this concern. That the whole complex represents not only the Permian, but also the Carboniferous, I hope and expect, may be realized by finding proper fossils in the future.

I wrote to Dr. YEN asking for recent information on the stratigraphy, especially of the Metamorphic Complex and the Slate Formation of Taiwan. He kindly explained the situation.[38] He explained the gist not only of the Tananao Schist, but also of the Slate Formation, and the succeeding formations as well. The following is the substance of this communication.

The Tananao Schist is developed in the upstream regions of the Tananao and Tachosui rivers and their tributaries in the northern part of the eastern Taiwan. The zone of this rock group extends for southward to the northwestern vicinity of the city of Taitung. The area of this rock group, as a whole, forms a synclinorium of a conspicuous scale, accompanied within by the folds of minor scales, variable in size and of different periods of formation. The fossil evidence is only of the Permian age recognized at the present.

According to the dominant features of the constituting rocks the whole Tananao Schist can be grossly characterized part by part. YEN defines it in the following way.

Upper Part:	sandstones and shales
Middle Part:	limestones, tuffs, sandstones-shales, fusulinids and corals in limestones
Lower Part:	arkoses, sandstones

Of these rocks, limestones and tuffs are dominant on the eastern, that is, the Pacific side of the Axial Range, while on the west side the facies are chiefly of sandstones, shales, tuffs and occasional limestone.

The metamorphism of the rocks represents the degree indicative of the chlorite and biotite zones: the injections into the rocks show the stages of the epidote-amphibolite or hornblende-hornfels facies and in part the stage of glaucophane schist. The age of the metamorphism is conjectured to be between middle and late Mesozoic: the late Cretaceous pegmatitic injection accompanied: the injection of the migmatitic parts of the Gneiss may be of the early Tertiary age, probably being about 50 Million years old.

As YEN's communication touched also the Slate Formation, I will passingly refer to it in advance of explaining our former knowledge of the same Formation summarized in Table 1.

The Slate Formation covers the Tananao Schist unconformably. In the Axial

Range it froms (Mesozoic?)–Eocene–Miocene. Westward, in Hsuehshan range the Oligocene is recognized between Eocene and Miocene, thus, latter two are generally regarded unconformable. The structure as a whole is a low angle geosyncline of a grand scale devoid of complicated structures. Owing to the test borings it is certain that the Eocene or the older beds lie unconformably in west Taiwan under the middle Miocene beds; this relation resembles that revealed in the Axial Range region.

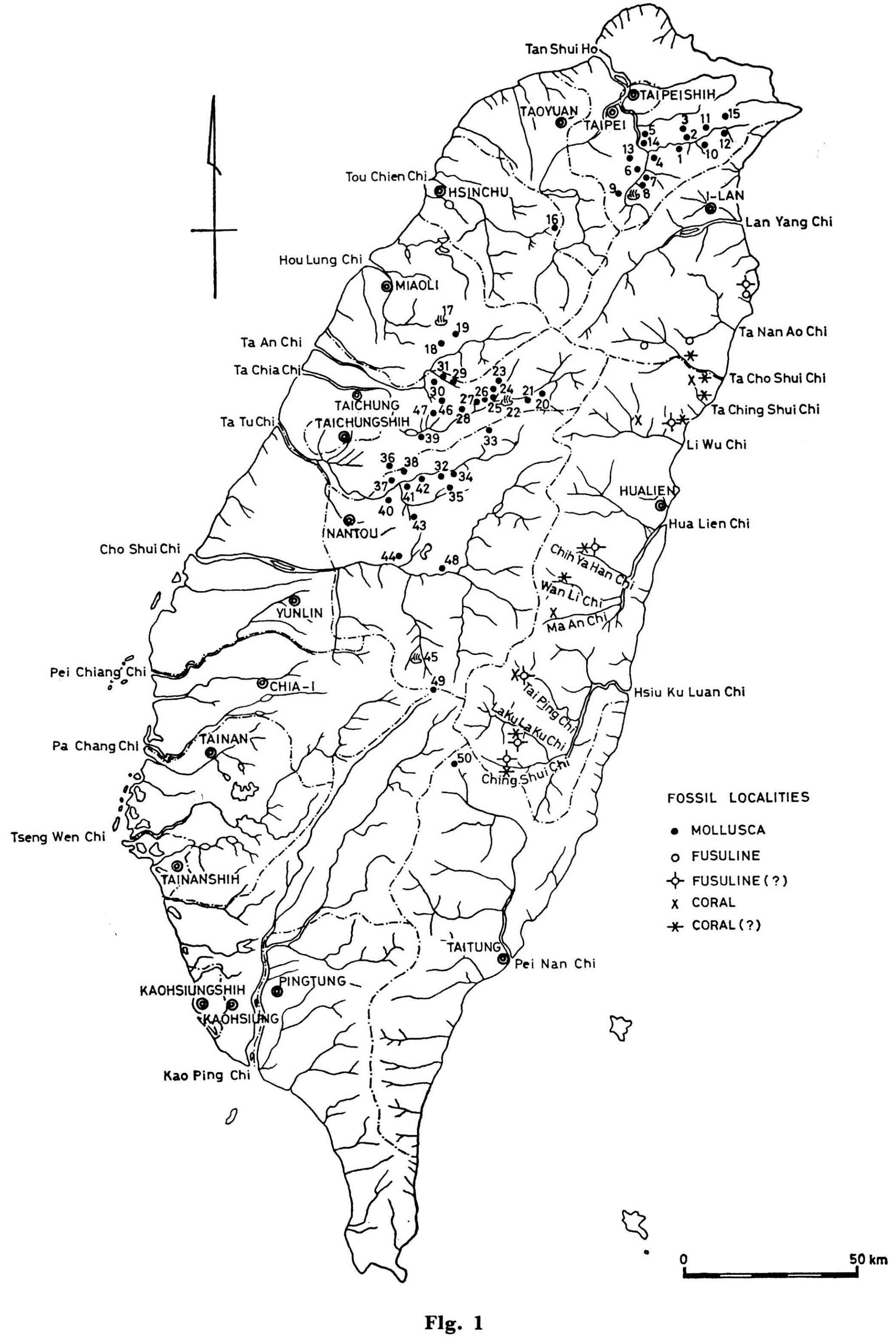
C. The Slate Formation

The western flank of the Taiwan Mountains or the Axial Range is composed chiefly of an apparently very thick sequence of hard, black slates. This sequence comprises, at different places, beds of sandstones ordinarily in meager volumes; besides, intercalated thin beds of conglomerate and limestone also are found. The stratigraphical relations with the Metamorphic Complex has been explained elsewhere. The Slate Formation as a whole has been used to be divided into two parts; the Lower or the Suo Series, and the Upper or the Urai Series. Beside the generalized divisions, several indefinite local names have been proposed for rather local isolated exposures where some fossils are actually obtained but devoid of reliable evidence for correlation among them. Actually, the Slate Formation is, just like in the case of the Metamorphic Complex as a whole, quite severely disturbed, strongly crumpled, traversed by complicate fissures, faults, etc., and the recognition of the order of bedding rendered extremely intricate. Often different blocks of the same formation are apt to be called by different names. At certain places, however, in the Slate Formation which, as a whole, has been said to be deficient in fossils, some organic remains have been yielded. The following is a list preliminarily recorded by the late Prof. K. Tan, in 1942.[39]

Upper Slate Formation:
- *Cyclammina* spp.
- *Assilina formosensis* Hanzawa
- *A. niitakaensis* Tan
- *Heterostegina* sp.
- *Lepidocyclina* (S. S.) *formosensis* Hanzawa
- *Operculina* sp.
- *Discocyclina* spp.

Lower Slate Formation:
- *Camerina* spp.
- *Amphistegina*? sp.
- *Discocyclina* (s. s.) spp.
- *Orbulina universa* d'Orbigny

Beside these foraminifers several marine shells were described by M. Yokoyama, Tan and others. They are *Crassatellites nipponensis* Yokoyama and *Pholadomya margaritacea* (Sowerby); both are Eocene in age. There are some others that are


Tan Shui Ho
TAIPEISHIH
TAOYUAN
TAIPEI
Tou Chien Chi
HSINCHU
I-LAN
Lan Yang Chi
Hou Lung Chi
MIAOLI
Ta An Chi
Ta Chia Chi
TAICHUNG
TAICHUNGSHIH
Ta Tu Chi
Ta Nan Ao Chi
Ta Cho Shui Chi
Ta Ching Shui Chi
Li Wu Chi
HUALIEN
Hua Lien Chi
NANTOU
Cho Shui Chi
Chih Ya Han Chi
Wan Li Chi
Ma An Chi
YUNLIN
Pei Chiang Chi
CHIA-I
Hsiu Ku Luan Chi
Tai Ping Chi
La Ku La Ku Chi
Ching Shui Chi
Pa Chang Chi
TAINAN
Tseng Wen Chi
TAINANSHIH
TAITUNG
Pei Nan Chi
PINGTUNG
KAOHSIUNGSHIH
KAOHSIUNG
Kao Ping Chi
FOSSIL LOCALITIES
MOLLUSCA
FUSULINE
FUSULINE (?)
CORAL
CORAL (?)
0
50 km

Flg. 1

rather widely distributed in the Cenozoic, namely, *Corbicula*, *Pecten*, *Cyprea* and the like.

In a personal communication, YEN mentioned also the current status of the Slate Formation concisely. The Slate Formation is of a vast thickness and ranges in age from the Mesozoic (?) to Neogene. The Oligocene formation is lacking except in the northern part around Hsueh-shan, the Eocene and the Miocene formations being unconformable in general. The Slate Formation forms a low angle synclinorium as a whole of an enormous scale, though not so complicated in structure as has generally been considered. The Formation can be traced along almost the whole length of the Axial Range, and extending down the western slope for some distance. It is generally fossiliferous, often proliferous in certain horizons. (The occurrence of some Eocene fossils in certain horizons of what was regarded the Slate Formation suggested that the Metamorphic Complex also might belong to the Tertiary.)

The late Prof. K. TAN was successful in collecting numerous Eocene and Paleogene fossils from various localities in Taiwan. He studied them paleontologically in universities in Taipei and Akita (Japan), and around 1950 prepared a report, which is quite comprehensive.

Comparing the maps of the fossil localities of TAN and YEN, there is a palpable boundary between the two areas, the one on the western slope of the Axial Range, and the other on the eastern. The former area is where TAN collected Eocene and Paleogene molluscs in as many as 50 localities, while the latter includes fewer localities of the younger Paleozoic fossils. The terraine of the former is chiefly of Slate Formation, while the latter, of the Tananao Schist land. Neither of the areas seem to transgress the frontier, however (See Fig. 1).

In 1961, some unusual information regarding the historical geology and the paleontology of Taiwan was made known. It was the discovery of an ammonite and some other fossils of the Jurassic age in the central plains region of Taiwan. According to Prof. C. C. LIN[40] of the National Taiwan University, these fossils were struck by one of the test bore holes for oil carried out by the Chinese Petroleum Company at a well near the town of Peichiang (or Peikang), northwest of

Fig. 1. Distribution of Localities of the Permian and the Paleogene Fossils in Taiwan. Dr. K. TAN, about 1950, drafted a chart showing the distribution of his Paleogene and Eocene molluscs (and foraminifers). Dr. T. P. YEN, subsequently, in 1953, prepared another similar chart on which he plotted all the known localities of his Permian fossils —the fusulinids, unaware of TAN's work. I was interested to compare these two charts,* interested with regard to the problems of stratigraphy, sedimentology and structural geology. In order to make the comparative study of the charts more easy, I asked Mr. Y. SAITO of the National Science Museum for help. He made a single chart uniting the two, and on it he plotted all the localities of TAN and YEN. This shows that the Paleozoic and Paleogene "domains" are almost distinctly divided but one—No. 50, one of the Paleogene molluscan localities. May not this be more or less significant for further contemplation for disclosing the problems of the stratigraphical, structural, etc. relations of the Tananao and the Slate Formations? (I.H.)

* K. TAN (in the press): The Paleogene Stratigraphy and Paleontology of Taiwan, p. 22, fig. 4.
T. P. YEN, See Note 35 (1953), p. 24, fig. 1.

the city Chai, Tainan Prefecture. The depth of the well was 1,692.8 m from the surface, so that the horizon of the fossil bed may not be more than a few meters higher than the depth below sea level. The quite well-preserved ammonite was tentatively identified as *Holcophylloceras* aff. *mediterraneum* (NEUMAYR) by LIN; the associate fossils were fragmentary specimens of Belemnites, and Brachiopods, together with a few fragments of terrestrial plants. These fossils were buried in a "hard, compact, fine-grained, carbonaceous sandstone" (LIN). The ammonite was briefly described and illustrated by LIN in *the Proc. 9th Pacific Science Congress*, vol. 12. Fragments of another kind of ammonite was reported to have occurred at a different level of the test well.

It was ascertained by this discovery that the West Taiwan Tertiary formations embodied oil and coal concealed beneath not only the Paleogene and Neogene formations but also a bed with some Jurassic fossils, and possibly a more comprehensive parts of the Mesozoic formation, as it seems to have been presupposed by some geologists in Taiwan the early days. As early as in 1910 Y. DEGUCHI,[41] assumed the existence of the Paleozoic and the Mesozoic formations in Taiwan. K. MURAYAMA,[42] a member of the OOINOUE party exploring the oil resources, happened to pick up a piece of sandy shale with an obscure remain that looked like an ammonite impression. It was found in the upstream region of the Ninaichi, near Hengchun, Kaohsing Prefecture. The sandy shale belonged to the Lower Arishan formation. Provided that the fossil is really an ammonite the rock cannot but be of the Mesozoic age.

In regard to these occurrences, DEGUCHI's expression of his supposition on the possibility of the existence of the Paleozoic and the Mesozoic, "the late Paleozoic—early Mesozoic" and "the Cretaceous—the Tertiary," is noticeable. This is in recognition of the more recent advancements in science in Taiwan.

In reality, the knowledge of the Mesozoic of Taiwan has been much advanced by the geologists in Taiwan. An article by YEN, SCHENG, KENG and YANG, "Some Problems on the Mesozoic Formation of Taiwan" (1956)[43] may be regarded as representative.

Much more information on the Mesozoic of Taiwan is expected as well as information on the relations with the Mesozoic and the Paleozoic.

Here, before summarizing the Neogene Formations of Taiwan, the stratigraphy and the historical geology by the close of the Paleogene may be reviewed according to recent data and information mentioned above. For further detailed studies, contributions by researchers in Taiwan along these line also are awaited.

1) The Tananao Schist may involve the Carboniferous formation, or, at least its part or parts, although this is not obvious at present.
2) The Jurassic formation may be a part of the Mesozoic formation, which may include the whole sequence of the Jurassic and the Cretaceous upwards; a part of the upper Cretaceous is said to be indicated by such fossils as *Elephantaria* sp. and *Astrocoenia* sp. Downwards, the fossiliferous horizons of

the Jurassic may have preceding horizons, possibly representing the upper part of the Slate Formation, together with the older Triassic part.

3) The structural relations of the Pre-Tertiary and the Paleozoic formations, and those of the Paleogene and the Neogene formations are important and at the same time interesting as problems. Perhaps a number of borings reveal information on such problems.

In light of this information Table 1 should be amended. In the column "Paleogene" instead of Paleogene, Paleozoic and Mesozoic, with their subdivisions, should appear.

In this note the so called Metamorphic Complex and partly the Eocene or the Paleogene formation have been taken up for discussion, on one hand, and the Jurassic as the representative of the Mesozoic on the other. Scrutiny may further reveal data to throw some light on the restoration of deficient Ages and Systems.

The general stratigraphical sequences must have been compiled officially, though it was not yet made available for me. The following were at my disposal:

CHANG, Li-Sho (1953): a. Geohistory of Taiwan; b. Stratigraphy of Taiwan. "The Geology of Taiwan" The Economy Research Section of the Taiwan Bank.

LIN, C. C. (1964): Geographical and Topographical Documentary Literature (Chinese). Documentary Literature of Nantouhsien, 12.

As I have no information on current progress, explanations concerning the Cenozoic, especially the Neogene formations, can be found following in the main summaries of HAYASAKA, LIN and YEN, 1948.

D. THE BASIC AND ACIDIC INTRUSIONS

The cardinal members of the basic intrusives are amphibolites, schistose and otherwise, gabbro, diabase and serpentine: these have been referred to in the foregoing pages. These rocks are the products of metamorphism together with the Paleogene (so assumed at least for the time being) sedimentaries. Besides, there are, in association with the Metamorphic Complex, lamprophyre dykes, augite minette, biotite minette, augite spessarite, biotite spessarite in association with the Metamorphic Complex, without showing the schistosity as recognized in the latter. Consequently, the last phase of the magmatic injection process is considered to have lasted until after the dynamic metamorphism came to an end. The gabbro, peridotite and serpentine found around Taito in the Taito Coastal Range are older than the Neogene formation developed in the region. Moreover, the xenolithic capture of peridotite by gabbro is known in this area.

To the acidic intrusives of the same region belong granite, granite-gneiss and hornblende-amphibolite. Non-schistose rocks like pegmatite, quartz porphyry and quartz veins seem to correspond in phase to the lamprophyres mentioned above.

In the central regions of Taiwan, along the highways across the Axial Range, layers of diabase tuffite and volcanic agglomerate as well as porphyrites associated with the Slate Formation are sometimes met with. Similar cases are rarer northward, the occurrence of tuffaceous zones being known at a few places in the proximity of Taihoku as well as in the hill region east of Taito.

E. Regional or Dynamic Metamorphism

Considering the time or period of the metamorphism which produced the metamorphic rocks referred to above, it is so far certain that (1) none of those injection rocks ever affected the Neogene sediments and (2) those latter do not show the symptom of regional or dynamic metamorphism. On the other hand, the Oligocene fossils have been discovered quite limited outside Kotosho islet; the lower division of the Neogene formation had not been discovered in the middle part of Taiwan; and the development of the latter appears to be quite unsteady in the southern Taiwan.[44] These facts taken together indicate that the dynamic or regional metamorphic processes that seem to have taken place have to be assumed to be the phenomena which took place after the Eocene period and before the Miocene. Geographically considered, and judging from the trend of distribution of the metamorphic rocks, the process of metamorphism appears to have been most severe where the general north-north-east—south-south-west trend of the axis of Taiwan turns all of a sudden toward the east: the energy is considered to have been mitigated on proceeding southward.

F. The Kaizan Group

The Kaizan Group is just as was defined by Yabe and Hanzawa (1930),[45] and includes the Upper Arisan formation of Ooinoue.[46] In other words, the coal-bearing and petroliferous formations of the northern part of Taiwan are embraced in it. It corresponds to what was named the Shukkoko formation by authors in Shinchiku Prefecture.

The formation is schematically divided into three rhythmical subdivisions as follows:

c)	Upper Kaizan beds ca. 800m	Upper marine beds Upper coal-bearing beds
b)	Middle Kaizan beds ca. 1,300–15,000m	Middle marine beds Middle coal-bearing beds
a)	Lower Kaizan beds ca. 1,000m	Lower marine beds Lower coal-bearing beds

a) The lower coal-bearing beds are a succession of a coarse-grained quartz sandstone and overlying beds of sandstone and shale in alternation, the shale intercalating seams of coal.

The lower marine beds are specified by certain foraminifers of Miocene age, such as *Lepidocyclina taiwanensis, Nephrolepidina verbeeki Miogypsina mammillata, M. inflata,* besides *Cellepora formosensis.* These species collectively indicate the Burdigarian in age. There are several other forms of fossils known including *Cyclo-clypeus communis, Lithothamnium* cf. *ramosissimum, Pecten (Amusiopecten) yabei, Echino-discus formosus,* and *Schizaster taiwanicus.*

The lower Kaizan beds, however, are not found distributed around the Shuk-koko oil field itself.

b) The middle coal-bearing beds including three seams of coal yielded in-complete specimens of *Ficus, Cinnamomum* and a few other plant remains. The accompanying middle marine beds yielded some fossils at certain places. The more important among them hitherto collected are: *Operculinella bartschi ornata, O. b. multiseptata, Operculinella venosa, Amphistegina communis,* and some smaller foraminifera like *Textularia, Biloculina, Globigerina,* etc. Beside these foraminifers *Pholadomya, Clypeaster, Astryclypeus integer* and the like were discovered.

The middle Kaizan division is very well exposed in the neighbourhood of the anticlinal axis of the Shukkoko oil field, where the successions of the formation are well recognized: an alternation of sandstone and shale at base, sandstone, shale and another alternating beds of sandstone and shale at the top.

c) The upper division is best developed in Shinchiku Prefecture. Here the coal-bearing series is characterized by the development of a coarse-grained white quartz sandstone, associated with thin beds of shale and sandy beds. In this upper division there are three principal seams of coal, which, as a whole, are not of an excellent quality: and the thickness also is rather variable, and neither is the extension constant. The overlying marine bed is a medium-sized calcareous sand-stone, which is sometimes glauconitic in nature. In this marine bed is somewhat fossiliferous, containing abundant specimens of *Operculina venosa* and occasional molluscs among which *Pecton (Amusiopecten) yabei* may be worthy of note as an index.

In eastern Taiwan, in the Taitung Coastal Range, a series of shales and sand-stones is considered to correspond to the lower Kaizan beds, chiefly by reason of the paleontological correlation: the occurrence in certain calcareous beds at certain places of *Miogypsinoides, Amphistegina* and some others have been discovered.

In the mountainous region around Arisan in the middle central part of Taiwan, the geology is mainly of a series of sandstone and shale, mostly in alternation, and in part cross-bedded. The total thickness is assumed to be about 800 m. Fossils are rare except for some molluscan shells found in the upper part of the sequence.

G. The Byoritsu Group

This group of formations is quite well developed in the Shinchiku Prefecture and southward from there. But, farther north, around Taihoku, this group is incom-pletely found sporadically. The lower division of this Group is dominantly shaly, and the upper part is mainly the alternating beds of sandstone and shale. The former was named the Kinsui Shale, and the latter the Takuran sandstane and shale, respectively. It is limited below by the Daiho beds or the Kantozan beds by Lin, and above by the base of his lower Tokazan beds. The Kinsui Shale is about

1,000 m thick in Shinchiku Prefecture, but is barely 500–600 m in Taihoku Prefecture in the north. This Shale formation tends to increase in thickness southward from Shinchiku Prefecture. At the same time it gets somewhat richer in sandstone beds, as is seen in the Kwanshirei and the Mokusaku beds, in Tainan Prefecture; the total thickness around here increases up to about 2,000 m. The Kinsui Shale is rather poor in fossil content: however, molluscs and the so-called smaller foraminifers are common; so also with some echinoids, namely, *Clementia nonscripta, Amusium* cf. *pleuronectes, Rapana bulbosa, Tonna costatum, Xenophora* cf. *solidiformis, Operculina venosa, Streblus schroeteriana, Clypeaster* cf. *japonica, Galena granulifera*, etc.[47]

The Takuran Sandstone and Shale formation tend to form the structural topography of the so-called "homoclinal ridges" in certain regions. The Unsui and Koteiko formations of southern Taiwan correspond to this. This formation is only about 500 m in thickness in the northern part of Shinchiku Prefecture, but their thickness is also augmented in the south, attaining about 1,800 m in the Taichu Prefecture, and culminating to nearly 2,500 m in Tainan. In Tainan Prefecture, where some local names are proposed for certain local beds, as for instance, the Unsui beds, or Koteiko beds just referred to. In this district this bed is characterized in intercalating a few thin Oyster beds with swarms of the gigantic valves. This may possibly have some bearing on the consideration of ecology and sedimentology of this formation.

As to the occurrence of fossils of this formation, there are a number of foraminifers that are of the same species as those from the Kinsui shale, and besides, there are many more remains of molluscan shells: the more common forms being as follows: *Pecten laqueatus, Ostrea gigas, Arca inflata, Anadara granosa, Architechtonica perspectiva, Fusinus nodosoplicatus, Oliva mustellina, Turritella filiola, T. terebra*, etc. The bluish gray sandy shale of the Takuran Sandstone and Shale seem to react to the process of weathering in an unusual manner; it is presumed that this is the cause for the so-called "badland" topography in the southern part of Taiwan. Besides, a similar phenomenon is known to take place in a certain part of Taito Prefecture in southeast Taiwan, but the details about the Byoritsu Group in the Taito Coastal Range are not yet known.

H. The Tokazan Group

This is a group newly proposed by Hayasaka, Lin and Yen[48] to include the upper part of the Byoritsu beds and the overlying Shokkozan beds of the former usage. The lower part of the Tokazan Group is dominantly sand, and coincides with what had been called by some people the Tsusho Sandstone, and the upper division, the Shokkozan Conglomerate.

The Tsusho Sandstone consists in sandstone that is yellowish gray to gray in colour, intercalating beds of mudstone and gravel, and often containing pieces of carbonized drift wood of considerable size, here and there. This formation had been often called the lower Tokazan formation in Taichu Prefecture, and Kityo beds and so on in southern regions. In the Koshun region, that is the southernmost district of Taiwan, the richly fossiliferous Shiko beds and possibly also, the underlying *Globigerina* Sand minutely studied by the late K. ISHIZAKI[49] geologically correspond to this. In the northern regions especially, this formation yields very abundant molluscs and some other kinds of fossils at various places. The beach of Hakushaton close to the village of Tsusho in Shinchiku Prefecture, for instance, may be mentioned as the typical locality; almost all of the numberless fossils formerly labelled to have occurred at Hakushaton have now to be recorded as being from Tsusho, and most of them are not to be called the fossils of the Byoritsu formation. The fossil collected were far more than 200 species. According to S. NOMURA,[50] the species inclusive of varieties he listed in a monograph (1935, 1938) amount in reality to over 400, including 13 Scaphopoda, 73 Pelecypods, and 275 gastropods. If analyzed stratigraphically, the great majority of them represent the Recent to the Pliocene forms. Among them, however, those limited to Pliocene are 31 Pelecypods, 69 Gastropods and 1 *Dentalium*. These 101 species correspond almost all to those introduced as new from the so-called Byoritsu formation by NOMURA and YOKOYAMA. The old known Pliocene cosmopolitan species are only three among pelecypods, namely, *Arca (Arca) sedanensis* MARTIN, *Pecton (Vola) javanus* MARTIN, and *Cardium (Fragum) alfuricum* (FISCHER). Of the 69 gastropods *Clavatula serana* FISCHER is Miocene (?)-Pliocene, *Astenostoma epitonica* (FISCHER) and *Clavus tjibaliumgensis* (MARTIN) are Pliocene. All the others are, as stated above, known from the Pliocene to the Recent, and almost all of them are possibly living in the actual sea around the archipelagoes of Japan and the Philippines, as well as Malaysia. Comparing them as the whole with the present day fauna of Taiwan in general, it seems that there is some disagreement.

The Pliocene marine shell fauna represented by the fauna of Tsusho where compared with the present marine molluscan fauna, species by species, do not seem to show such a difference in the climate about the close of the Pliocene to provoke any perceptible ecological influence to the shore shell fauna.

The following is the list of some of the more significant molluscan species.

Anadara granosa (LIN.)
A. tricenicosta (NYST)
Trisidos kiyonoi (MAKIYAMA)
Cucullaea granulosa (JONAS)
Pinna attenuata REEVE
Chlamys (Chlamys) squamata (GMELIN)
C. (Decatopecten) plica (LIN.)
Pecten (Vola) naganumanus YOKOYAMA
P. (Amusium) pleuronectes (LIN.)
Placuna placenta (LIN.)
Anomia lischkei DAUTZ. & FISH.
Ostrea denselamellosa LISCHKE
O. gigas THUNBERG

Crassatellites loebecki (KOBELT)
Dosinia (Phacosoma) gruneri (PHIL.)
D. angulosa (PHIL.)
Chione (Clausinella) foliacea (PHIL.)
Anomalocardia impressa (ANTON)
Paphia (Paratapes) undulata (BORN)
Aloides erythrodon (LAM.)
Dentalium (Dentalium) hexagonum GOULD
Umbonium (Suchium) moniliferum (LAM.)
Turritella filiola YOKOYAMA
Architectonica perspectiva (LIN.)
A. maxima (PHIL.)
Cerithidea (Cerithideopsilla) ungulata (GM.)
Batillaria zonalis (BRUG.)
Xenophora (Tugurium) exuta (REEVE)
Strombus taiwanicus NOMURA
Natica (Notocochlis) rufilabris REEVE
Phalium japonicum REEVE
Bursa (Gyrineum) rana (LIN.)
Murex ternispina (LAM.)
Nassarius (Alectrion) canaliculatus (LAM.)
N. (Niota) gemmulatus (LAM.)
Oliva mustellina (LAM.)
Mitra (Cancilla) flammea QUOY et GAIM.
M. (Scabricola) yokoyamai NOMURA
Turricula byoritsuensis NOMURA
Turris (Turris) oxytropis (SOWERBY)

Beside such an abundance of mulluscan fossils, this formation has yielded several echinoids[51] such as *Echinarachnius (Scaphechinus) mirabilis* (A. AG.), *Astriclypeus manni* (VERRILL), *Breyinia* spp. and some other genera, often beautifully preserved. In the same formation developed around Shiko, to the south in Takao Prefecture, three species of *Pictothyris* (Brachiopoda)[52] were collected, together with almost equally prolific shells.

In Taiwan, various mammalian[53] fossils, mostly fragmented, have been unearthed from time to time, in the Prefectures of Shinchiku, Taichu and Tainan. In most of the fossil localities, the mode of their preservation is not consistent. At Sachin, in Tainan Prefecture, where such mammalian bones have been most frequently collected, they were found washed out on the bottom of the stream, with fragments of shells and also of pieces of carbonized drift wood. The mammalian remains known to include something like *Cervus (Sika) taiwanus*, *C. (Deperetia) kazusensis*, *Bison geron*, *Rhinoceros* sp. nov (?), *Stegodon sinensis*, *S. insignis*, *S. orientalis*, *Elephas indicus buski*, *E.* cf. *trogontheri*, etc.: a fragment of a scull of Crocodilia was once reported to have been discovered from Satin.

After careful exploration, it was ascertained that these mammal or rather vertebrate remains were originally embedded in the Kicho beds, in Tainan Prefecture, that is a bed which stratigraphically almost corresponds to the Tsusho Sandstone bed.[54]

A few words on the Shokkozan Conglomerate bed which overlies the Tsusho Sandstone. It is a thick conglomerate bed, gray in colour, and is intercalated with sandstone beds sporadically. The Shokkozan bed was formerly regarded as the upper part of the Tokazan group, and is very conspicuously developed in the Prefectures of Shinchiku and Taichu, attaining the thickness of from several hundred meters up to over a thousand meters. Because of the particular, loose and brittle nature of the rock, and being tinted deep ochre, it is severely eroded to induce the so-called earth-pillar pattern. Such a rough exposure of the ochre-coloured conglomerate cliff reflecting the evening sun glows magnificently, hence it has been called the Kaenzan—"flaming hill" for a long time. In all of Taiwan there are several places where similar geology and topography present the "flaming hills" of similar landscapes. The most graceful, however, is the one in Taichu Prefecture, about 15 km southeast of the city of Taichu. In the sandy part at the basal horizon of this Shokkozan Conglomerate a few fresh-water or brackish-water shells, like *Corbula, Unio, Potamides fluviatilis* and the like are buried. This may possibly throw light on discerning the condition of the sedimentation of the formation.

Concerning the Shokkozan Conglomerate, details have been observed and much has been discussed. From most of what has been studied, it is almost unanimously believed that it represents the lower part of the Pleistocene formation.

As regards the stratigraphical relation between the Tokazan and the Byoritsu beds, they are decidedly conformable to each other as far as is known in western Taiwan, and it is assumed that the same sequential relation may prevail all over the island.

In the meantime, the Shokkozan Conglomerate bed, that is the upper Tokazan bed, wherever developed, is overlain by younger sediments with clino-unconformity. The explanation for this is that after the deposits of the Shokkozan Conglomerate were laid down the land was raised with accompanying folds and thrusts. The volcanic activities which erupted the Daiton Volcanic Group were to follow.

I. Upheaval, Folding, Thrusting, Volcanic Activity and Erosion; Glaciation

It is said that in the Taito Coastal Range, the Shokkozan Conglomerate unconformably lies on the eroded surface of the Byoritsu Group, and the succession as a whole is reversed by a tectonic disturbance. If it is really the case, there must have been a crustal movement of some sort before the deposition of the Shokkozan Conglomerate. This cannot but be considered exceptional in the recent historical geology of Taiwan, however. In western Taiwan where the Neogene formations are very widely spread and well developed, the Shokkozan conglomerate always concordantly succeeds the Tsusho Sandstone, and the latter and the Byoritsu Group are also conformable. The Conglomerate, on the contrary, is always clino-unconformably overlain by younger formations. The period or phase of the crustal movement following the Shokkozan Conglomerate is characterized by the dominance of folding and thrusting. The present-day Axial Range region of the island seems to have been highly raised along with the folding of the crust. This movement of the upheaval had been at work for some time, but it seems to have culminated in this period. The actual configuration of the island of Taiwan is believed to have been decided by this crustal reformation. The geographical conditions were almost the same as they are now, and the sedimentation of rocks took place in flood plains, basins, and shore zones, forming terraces, fans, taluses and the like everywhere. Along the shore, especially in the southern part, coral reefs developed vigorously, and they remain as raised reef limestones at present.

As is shown by certain marine charts around Taiwan, there are a few drownd valleys, signifying the recent subsidence of the dissected land of Taiwan. The most evident is the one which is the submarine extention of the Shimo-Tansui-kei, south-east of Takao harbor. In 1927, on the occasion of the 5th Pacific Science Congress in Java, YABE and TAYAMA read a paper concerning it.[55)a] Unaware of it HAYASAKA prepared a paper regarding the same, the main points being similar.

"In the later Pliocene period the island of Taiwan was about 1,000 m higher than it is now. During the course of the subsequent drowning, which was less conspicuous northwards, coral reefs were formed in the south, ... while gravel was deposited in the north where progradation was particularly vigorous. The general cooling, and the lowering of the sea level, of the Pleistocene age, caused the deadth of coral animals. It was immediately followed by an uplift of land, in the course of which the rise of the water level resulted by the melting of the polar ice gave a chance to the formation of the younger coral reefs. ...." The land uplift still continued and consequent valleys were in the making.

"Glaciation might have taken place in Taiwan when it was 1,000 m higher, but the topographic characteristics are not likely to be preserved under such a climatic condition like this, and especially where the mountain ridge is composed of very fissile slates and sand-stons" in the main.[55)b]

The volcanic activities were also powerful in the northern part of the island and in the dependent islets. It is important to note that the Daiton Volcanic Group north of Taihoku seems to have started as a submarine eruption, because the volcanoes as a whole are fringed all around with remnants of several succeeding series of marine terraces.[7)]

In the northernmost region of the island where volcanic energies manifested themselves in vigorous activities, two areas are distinguished. The Daiton volcanic mountains form the main area where there are various kinds of andesite lavas together with some pyroclastic rocks. There we see lavas of pyroxene andesite, two-pyroxene andesite, hornblende-two-pyroxene andesite, two-pyroxene-hornblende andesite and hornblende-andesite, with which andesite conglomerates and tuffites occur in association. These rocks are distributed in Kannonzan, Sho-Kannonzan, Daitonzan, Shichiseizan, Shabozan, Kiirunzan, and several others. The other area includes the mining fields from around Zuiho and eastward. Here biotite-hornblende-dacite is found, and chiefly in the forms of necks and sills, as are observed in Kiirunzan, Butanzan, the main mines of Kinkaseki, Sozan and Keimorei.[24),1)]

This was really a very active period of volcanic energy in the geohistory of Taiwan. But it does not mean that there had not been any other phases of the manifestation of magmatic energy before, and possibly also after this period. During the latter part of the Miocene period, that is, in association with the upper Kaizan beds, there were basaltic activities as are represented by the dykes and sills of olivine-basalt, olivine-dolerite, and thoreiite (teschenite) found in the area extending over the south-western part of Taihoku Prefecture (Sankyo district) and the north-eastern part of Shinchiku Prefecture (Kappanzan, Mabutoku, etc.).

The basaltic activities seem to have started somewhat earlier, and we see lavas, tuffites, and agglomerates of olivine-basalt, dolerite and teschenite that are in association with the lower Kaizan beds; they are observed at such places as Kiirung, Nanko-Daiko, Kokan, Shinten, Sanshikyaku, Seisuiko and Dairyo-Kinkaseki, all quite closely near Taihoku.

So far are the volcanic activities and volcanic rocks of the main island of Taiwan. Concerning those of the dependent islets hitherto on record may be summarized as follows:

North of Taiwan:

Agincourt Island—basaltic flow and andesitic or basaltic agglomerate
Crag Island—basaltic andesite flow
Pinnacle Island—basaltic andesite flow
Kiirun-to—dacite dyke

East of Taiwan:

Kizanto—andesite flow and andesitic agglomerate
Kashoto—the same
Botel Tobago Island—andesite and andesitic agglomerate, and exposures of serpentine at places
Little Botel Tobago—andesite and andesitic agglomerate

West of Taiwan:

Pescadores Islands—basalt flows (with quartz porphyry dykes in Huahsii)
Lambay Island—raised coral limestone

South of Taiwan:

Vele Rete Rock—unknown

Keeping pace with the uprising of the axial region of the island, a denudation of a great scale took place to result in an extensive erosion surface on which the Tableland Gravel was laid down. There are pebbles of andesitic lavas in gravel developed around the Daiton volcanoes. The great altitude reached by the island was high enough to provide natural conditions competent enough to cause the glaciation high up on the ridges and peaks. I had maintained this idea for some years, on account of various geological and geographical observations, until at last the geographers KANO[56] and TANAKA[57] discovered topographical and other favourable evidences a few years later. The uprising of the island was also the cause of the deposition of the Tableland Gravel formation which will be explained below.

J. THE TABLELAND GRAVEL AND THE OLDER REEF LIMESTONE

Over the surfaces of the series of tablelands lined up almost north-south, with that of Jurinko, immediately west of Taihoku as the northernmost member, followed by those of Shinchiku Prefecture (Toen, Chureki, Heichin), and Taichu Prefecture (Daito, Hakkei), a particular, somewhat unusual sedimentary formation is developed everywhere. It appears like a kind of terrace deposit. It is characterized by two unequal heaped-up layers; an ochre coloured sandy-clayey bed above, and a rather loosely consolidated conglomeratic or gravel bed, the two being clearly distinguished in appearance from each other. Besides, these tableland formations are slightly tilted but all with plain surfaces. The boulders and pebbles are mainly of hard sandstone, but in the northern region those of andesites are not uncommon; the boulders are often as large as a human head. The ochre soil above owes its colour to the cementing material which is strongly tinted with iron hydroxide, and is in appearance resembles what is called the "laterite."

Similar formations are found to develop also in the southern and southeastern districts, in which cases they are more isolated in distribution. Thus, it is conjectured that this formation might have been originally much more widely developed in this region, of which parts, however, have locally survived the degrading geological agencies that followed.

As this formation—the ochre solid and underlying gravel bed inclusive—was named the Tableland Gravel because it covers different older formations with clear unconformities everywhere. This surface of unconformity is presumedly the most extensive one in the Cenozoic sequence of Taiwan. Because of the very noticeable, loose gravel bed with its unusual occurrence was the name of the formation—the Tableland Gravel—proposed.

Concerning with formation YABE and HANZAWA[58] once propounded a theory that it is the Alluvial deposits accumulated at the foot of steep slopes of the high mountain ranges. However, after more recent, careful and detailed observations at numerous exposures, we discovered a very conspicuous fact to refute this; that the upper soil of the ochre colour and the lower gravel are everywhere very clearly distinguished in bedding, is an important phenomenon. Such an occurrence is a phenomenon expected only from an inundation of a grand scale. This latter idea seems to be supported by Y. TOMITA[59] who assumes his "lateritic slope" originally occupied a very extensive area, and the tilted blocks observed are the remnants of those "lateritic slopes."

What is called here the Older Reef Limestone is a formation including the "Ryukyu Limestone" so designated by some geologists in Japan and in Taiwan for some time. This so-called Ryukyu Limestone was designed to include an important formation which needs be distinguished from the definition often carelessly alluded to. Here is an example. On the top of the hill west of the old historical town of Koshun, there is a thick bed of *Globigerina* Sand.[60] This was included in the Ryukyu Limestone of YABE, HANZAWA and some others. It is very clear that this *Globigerina* Sand and the type of the Ryukyu limestone—say, that of Takao area, are different from each other either lithically or paleontologically; the mode of genesis cannot be the same. At Byobito, a promontory, south of Koshun, the coral limestone bed is divided into two, or possibly three, by intercalating beds of sandy shale with molluscs and brachiopods (especially known as of northern habitat in Japan) had to be investigated before the correlation was to be assigned.[61] Besides, there are many places along the seashore in the southern part of Takao fringed with living coral reefs, where number of low terraces, about twenty or thirty meters high, with abundant blocks and debris of reef corals are accumulated. In these blocks the structures are clearly preserved, but the stocks are more or less broken, and their postures are quite at random, as well as weathered to white, and the surface is more or less worn out: they do not form a rock either.

To make clear these different types of reef limestones and foraminifer limestone, the name "Old Reef Limestone" was proposed more recently. The "Ryukyu Limestone" may still remain intact especially in Okinawa, but in point of the geological antiquity, geologists should be somewhat careful not to mix up the different materials.

It is in order to avoid confusion that we proposed to take up the Older Reef Limestone:[62] by appending "Old," and the other, younger coral reef beds should be distinguished from the "Ryukyu" Limestone. The latter is assumed to correspond in the stage to the Tableland Gravel, because it overlies, in west Taiwan, the tilted blocks of the Tokazan Group.

Concerning the stratigraphical relations between the Tableland Gravel and the Old Reef Limestone, there had been some people who were inclined to regard that the former was deposited over the latter. In reality there are a few places where beds of gravel are found lying over the Old Reef Limestone, but these gravel beds cannot be identified with the latter. The form of the pebbles of the gravel are of different types, first of all: the thinner, loose and less massive. Consequently, it should be assumed, at least for the time being, the Tableland Gravel and the Older Reef Limestone might have been deposited almost simultaneously at certain different sedimentary environments.

All these younger formations are considered to have been deposited during the late Pleistocene period. Following this a period of crustal unrest is considered to have ensued, arousing dislocations, tiltings, necessarily accompanying the processes of erosion which is unavoidable. Thus, the period of the last phase of Pleistocene should have been closed.

K. Folding, Tilting, and Erosion: Earthquakes

After the deposition of the Tableland Gravel and the Older Reef Limestone, there ensued a period of crustal unrest in which faulting and tilting predominated, as has been summarized before. These tilted blocks are, without exception, inclined eastward. Further, many of the dislocations cut through these formations not only lengthwise, but crosswise as well. The crustal equilibrium does not seem to have been restored until now, and there are young fluviatile terraces traversed by faults. The destructive earthquakes that occur frequently in western Taiwan are considered due chiefly to the same cause, as was pointed out sometime ago by Hayasaka.

In regard to the topographical and structural features, the Tableland Gravel seems to find its equivalents in such remote regions as the Philippines, southern China, including Hainan island as far as was witnessed by us.[63] It appears quite likely that the Tableland Gravel may be a formation deposited on a vast area in the southeastern Asia including those mentioned and possibly elsewhere also. Such a land was separated into remote and unequal regions by the crustal revolutions which took place subsequently. The continent and the continental island like Hainan have been comparatively stable since, while the marginal islands of Taiwan and the Philippines have been further shattered and splitted into blocks, many of which were tilted. The patterns of the severe earthquakes, as far as I have experienced personally during the years of my life in Taiwan, should have some close relations with the crustal behavior or behaviors of the island.[64]

L. The Older Terraces, Fans, and Newer Raised Reef Limestones

The Tableland Gravel, as stated above, is very noticeable in Taiwan on account of the ochre-colored soil. Sometimes the secondarily deposited exposures are often deceptive, however. The Tableland Gravel often looks from afar as terraces and fans. The distinction between them and the genuine Tableland Gravel is rather easy, however. In the secondary, ochre-colored gravel bed, for instance, the cementing material consists of grains of variable kinds of sand and clay that are tinted; the sandstone gets perceptively paler toward the upper part; the tablelands do not present tilting, and the topography is different from the characteristic features popular in this region.

The terraces and the fans formed of the "secondary lateritic" deposits are commonly observed in the west-middle region of Taiwan quite often, especially in the basin regions of Hori and the Sun-Moon Lake basins.

In the southern coastal regions in the extreme south of Takao Prefecture, there are a few coastal terraces carrying the fragments of the reef-building corals, on the surface, as mentioned elsewhere. The best places to observe them are the regions in the neighborhood of Garanbi, the southernmost promontory, and Kaiko several km north. Along the shore of this region these younger raised Reefs or the coastal terraces are about 10–20 m above the living reefs, as observed above.

M. THE RIVER AND THE SHORE TERRACES, LUCUSTRINE DEPOSITS, AND RAISED REEFS

These are the records of the most recent formations. The raised coral reefs of this category are well formed along the shores of the southwestern and southern regions. Besides, even in the northeastern part of Taiwan they are often found as dissected fragments or remnants.

Lacustrine deposits indicate former water basins formed on the Older Terraces like those in the neighborhood of the Hori basin, as explained in I. In the northern Prefecture, Shinchiku and in the southern Taiwan, Older Fans often bear similar deposits. At Tamio, a village north of the city of Kagi, Tainan Prefecture, the surface of the Tableland Gravel was observed to be covered by a few meters of hard, white Clay Pan[65] of the freshwater origin. A similar case was reported to occur at a certain place in Shinchiku Prefecture, but I have not had a chance to visit there.

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41) DEGUCHI, Y. See Note 1h, Fukutome et al. (1911).

42) MURAYAMA, K. (1928), See Note 21, Oinoue, et al.

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45) YABE and HANZAWA (1930), See Note 27, YABE and NANZAWA (1930).

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47) Here and previously, reference to the occurrences and localities of fossils from various parts of Taiwan, especially of the Neogene have been made. The Paleogene forms have been connected with some frequency, but Neogene forms are far more abundant and are often found in profusion in some places. Except for the marine molluscs and foraminifers, the yield of most of them has not been enough to encourage monographic description: echinoderms may probably be counted one such group.

S. NOMURA's Catalogues (1935 and 1938) are voluminous and well-illustrated descriptions of Tertiary and Quaternary molluscs of Taiwan. YABE and HANZAWA wrote several papers about the foraminifers. A number of people can be counted among the foraminifer students of whom the name of the Late Dr. ISHIZAKI is noteworthy. He was a very energetic student, and wrote several important papers. His most memorable "List of Japanese Neogene, Pleistocene and Recent Foraminifera, excluding Orbitoidedae, recorded up to 1939" is one of his best known works.

Works on the foraminifera were expanded by CHANG, Li-Sho of the Geological Survey and young HUANG, Tun-Yu of the Chinese Petroleum Company at Miaoli; both greatly contributed to the stratigraphy, especially of oil field geology. Prof. LIN, C. C. of the Taiwan University is actively leading the study of fossil mollusca.

This present account is concerned with the paleontology, and also with geology of Taiwan.

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