THE PETROGRAPHY OF THE ROCKS OF HONG KONG

by

William Alfred Jones

A Thesis submitted for the Degree of Master of Applied Science in the Department of Geology

The University of British Columbia

April, 1927
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INTRODUCTION

Purpose

The suite of rocks described in this paper were supplied by the Department of Geology of the University of British Columbia and were collected by Dr. Schofield and Dr. Uglow while engaged on a Geological Survey of Hong Kong and the Leased Territories. This survey is being made for the Hong Kong Government by Dr. R.W. Brock with the assistance of members of the staff of the Geological Department of the University. Dr. Brock made the preliminary arrangements including a reconnaissance of the area to be covered. He was followed by Dr. Schofield who spent a field season of about six months on the general geology and areal mapping. Dr. Williams spent the 1925 session studying the sedimentary rocks of the area and Dr. Uglow investigated the igneous geology in 1926. Dr. Brock is at present in the field.

This paper is a description of the rocks mapped by Dr. Uglow, based on a study of the thin sections and specimens of his collection. The writer has been handicapped by not having seen the structural relations of the rocks in the field and by the fact that the work of Dr. Brock will modify some of the conclusions at present held regarding the age relations of the different intrusions. The general
geography and geology of Asia has been quoted from the works of previous writers in order to give the reader a better conception of the problems of the Hong Kong petrographic province.

Acknowledgements

The explanation of the work being carried on in China is Dr. Brock's and is taken from Mr. N. F. C. Davis' thesis "The Petrography of the Rocks of Hong Kong." This paper was prepared under the supervision of Dr. S. J. Schofield. Dr. T. C. Phemister has been of great assistance in the microscopic study of the specimens. His keen interest and many helpful suggestions are greatly appreciated. The geology of the Hong Kong area is taken from a preliminary paper by Dr. Brock and Dr. Schofield. The geography of the area is quoted from Mr. N. F. C. Davis' paper "The Petrography of the Rocks of Hong Kong." The general geology of Asia is quoted from Dr. Schofield's "Summary of the Geology of the Crown Colony of Hong Kong."
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CHAPTER I

GEOGRAPHY

(1) General Geography of Asia

"The continent of Asia can be divided into four great physiographic areas. Shelving gradually upward from the low plains of Siberia, the general continental level rises to a great central water-shed or divide which stretches from the Black Sea to Behring Strait. This divide is not always marked by well-defined ranges running in alignment with the general northeast-southwest direction. There are areas where the strike of the ranges is transverse to the water parting. Here lacustrine regions are found. The ranges are not high, seldom over 5000 feet in elevation.

"South of the divide the level drops to the central depression of the Gobi Desert, where the average elevation is probably less than 2000 feet above sea level. This depression extends westward from the eastern edge of the Gobi Desert to Chinese Turkestan, where it is limited by the great elevation of the Pamir.

"South of this enclosed depression are the highly

(1) From "The Petrography of the Rocks of the Crown Colony of Hong Kong" by Mr. N. F. G. Davis

(2) See Figure I, Page 11, from "Igneous Rocks", J. P. Iddin
elevated table lands of Tibet from 15,000 to 16,000 feet in altitude. These vast Tibetan highlands are bounded on the north by the Altyn-tagh and Kuen-lan mountain ranges and on the south by the Himalayas.

"The vast mountainous area stretching from the Amur river to the Caspian Sea forms the northern boundary of the lowlands of the Arabian, Indian, Siamese and Chinese peninsulas. Bordering the low plains of the Amur and of China are the shallows of the Yellow Sea and the islands of Japan and Formosa, once integral parts of the continent.

"Between the vast central highlands and the coast of southeastern China are a series of smaller mountain chains with a general northeast-southwest trend of which the Coast Range of China is one."

"This coastal area has been depressed so that the lower parts of the main valleys have been entered by the sea, giving a fiord-like appearance to the coast line. This also accounts for the numerous islands which fringe the coast and dot the entrances to the mouths of the great rivers."

Local Geography

(1) "The Crown Colony of Hong Kong is situated on the south-eastern coast of China in the mouth of the Canton River, near its northern shore. It includes the large island

(1) See Figure I, Page 11
of Lan Tau with an area of 60 square miles and an area of 376 square miles on the mainland, as well as the island of Hong Kong.

"The fine harbour of Hong Kong lies between the island of Hong Kong on the south and the leased territory on the mainland to the north. The passage inwards from the east is through Lyee Mun pass and the western portal of the harbour opens into the Canton river.

"The islands of Hong Kong and Lan Tau are simply two mountainous ridges rising out of the sea to the heights of 1850 and 3000 feet respectively. The general trend of these two islands is northeast-southwest, conforming in general to the structural direction of the whole region. The city of Victoria is built on the lower slopes of the north flank of the island and faces the harbour. Across the harbour on a narrow promontory on the mainland lies the city of Kowloon at the foot of the Kowloon hills, 1800 feet above the sea."
CHAPTER II

---GENERAL GEOLOGY---

Geology of Asia

"An examination of the geological map of the world will show that the Canadian-Baltid Archaean province forms the positive land mass to the north-west of the Asiatic-European basin of sedimentation or negative land mass. To the south-east of this basin lies a former positive land mass called Cathaysia by Grabau, which at one time formed a border land to the south-east of the basin of sedimentation. Cathaysia now lies beneath the waters of the Pacific Ocean.

"Sediments from both these positive land masses were carried into this huge basin forming the extensive deposits of Proterozoic, Palaeozoic and Lower Mesozoic strata which now outcrop throughout China and Europe. In places on this basin local upwarps have permitted erosion to remove some of these sediments so that patches of Archaean rocks are exposed in various parts of China.

"Great orogenic movements during the Upper Mesozoic era laid the foundation of the present continent of Asia because no marine Tertiary strata are known in China.

"These orogenic movements caused the sediment in the basin to be warped into folds which strike in a northeast-
southwest direction parallel to the present coast line of China from Hong Kong to Ning Po.

"Immense batholiths of granite were intruded simultaneously with the folding of the strata and correspond in strike with the main trend of the mountains so that the batholiths occur as narrow elongated masses. The most easterly of these batholiths stretches from Hong Kong to Ning Po, a distance of about 800 miles and is comparable in size and geological composition to the Coast range of British Columbia.

"The Cretaceous and Tertiary of China are represented by continental and marine deposits and it is in these continental Cretaceous strata that the remains of dinosaurs and their eggs have been found in the Mongolian desert.

"During the Miocene period the great mountain building forces which built the Alps of Europe and the Himalayas of Asia simply caused an uplift of the early Tertiary peneplain and renewed the activity of the agents of erosion. Hence the continent of Asia during the Cretaceous and Tertiary periods was above sea level and undergoing erosion.

"The Crown Colony of Hong Kong forms part of the eastern edge of the great Asiatic basin of sedimentation in close proximity to the down sunken land of Cathaysia. Associated with the sediments which occur in the vicinity of Hong Kong is the largest outpouring of acidic lavas in the
Geology of Hong Kong

"The oldest rocks are those of the Tolo Channel series consisting of conglomerates, sandstones and argillites exposed as remnants in the northwest half of the territory. Inclusions of marble in the Tai Mo Shan eruptive indicates that below the surface an older formation of limestone occurs. Ammonites found by Dr. Heanley of Hong Kong were examined by Dr. Grabeau of Peking who suggested a Lower Cretaceous age for the series, but better material collected by Dr. Williams in the course of the present geological survey of the territory has enabled J. J. Buckman to determine the age definitely. It proves to be Lower Jurassic, Lower Lias, Coroniceratan. These are the only rocks whose age has been definitely fixed by fossil evidence. The Tolo Channel series has been highly disturbed, folded, faulted and in places metamorphosed.

"The Repulse Bay Volcanics have been laid down on the eroded Tolo Channel rocks. They consist of agglomerate tuffs and ash beds. Between Tolo times and Repulse Bay volcanism no disturbance took place sufficient to raise the whole country above the sea, for obscure marine fossils are found in the ash beds. At the south-west end of the Territory, however, what are apparently Tolo rocks were somewhat
disturbed before the volcanics were laid down in them. There is, therefore, a time interval between. The Repulse Bay Volcanics may be Upper Jurassic in age.

"The extrusion of the above volcanics was apparently accompanied by a considerable amount of intrusion in the form of necks, sills and dykes, that invaded the Tolo Channel and Repulse Bay formations. These intrusions have been called the Tai Mo Shan Series. Volcanic flows continued after some at least of such unvasions as they are found on the east slope of Tai Mo Shan mountain holding fragments of the intrusives.

"The intrusives vary from quartz-felspar-porphyries to granite porphyries. They have been greatly disturbed, especially in the north-east portion of the area, where they are now schistose and mineralized. The Tai Mo Shan formation is extensively exposed forming the country rock of perhaps one third of the territory.

"Cutting all the above rocks is a porphyritic hornblende granite or granodiorite. It has contact metamorphosed the Tolo Channel rocks and the older rocks near its contacts hold numerous quartz veins. It has itself been disturbed and is epidotized along fractures and joint planes. Its intrusion probably followed a main period of mountain building, possibly the Jurassic Revolution."
"Cutting the Taitam formation is the much more acidic Hong Kong granite. It forms about one third of the country rock of the colony. Due to its mode of weathering as well as its abundance it is much the most conspicuous rock. It is cut by aplite and pegmatite dykes that also invade the neighboring rocks. The pegmatites have given origin to quartz veins, particularly in the granite itself, containing wolframite, tinstone and molybdenite.

"Apart from a little minor faulting and sheeting the Hong Kong granite shows no evidence of disturbance except on the north-west. Here, however, it has been deformed to gneiss.

"Its intrusion was probably the result of the disturbance that affected the already schistose Tai Mo Shan, the older quartz veins and the Taitam formation. This may well have been the Laramide Revolution.

"The last important intrusion is that of the Lan Tau granite porphyry. It varies from pink to dark pearl grey in color. The composition varies from that of a granite to a granodiorite. It cuts the Hong Kong granite against which it has broad strongly marked contact facies. The Lan Tau rocks have not been altered or deformed. They marked the last great disturbance, possibly the Miocene Revolution.

"Dark grey to black lamprophyre dykes cut all the
previous rocks. They are probably differentiation products of the Lan Tau magma and constitute the last phase of the igneous activity in the district.

"In addition, there are two sets of rocks whose relative ages have not been sufficiently established to place in the above sequence of formations.

"Occupying the peninsulas and islands of the south-eastern coast of the territory, north-east of Hong Kong island is a series of lava beds called the Rocky Harbour volcanics. The rocks consist of elongated pink felspar and quartz phenocrysts in a reddish to dark aphanitic groundmass. The formation is remarkable for the highly developed vertical jointing almost comparable to the basaltic jointing of the Geant's Causeway. On the seaward side cliffs 300 feet high are characteristic. Seacaves and stacks are common. Lamprophyre dykes are particularly numerous in this formation. They weather out readily, leaving steep walled inlets or valleys. In several cases the sea has eroded tunnels completely through the islands. This formation is cut by the Lan Tau and overlies a series of conglomeratic tuffaceous sandstones and argillites known as the Junk Bay formation.

"The Junk Bay formation rests on the Repulse Bay

(1) Dr. Brock is at present studying the relation of these rocks in the field.
volcanics, but holds bowlders of them, indicating a time break.

"After the last period of igneous activity there followed profound erosion. The district was then subjected to submergence greater than that at present observed as evidenced by rock terraces and hanging valleys. These indicate a submergence of possibly five or six hundred feet greater than now. This was followed by a rising of the land in stages. Rock terraces are particularly noticeable at about 480, 350, 200, 100 and at 50 feet. A small but frequently observed sea cliff occurs about 20 feet above sea level. A very recent elevation is shown by marine shells found a few feet above the present high tide. The coast, however, is still deeply submerged.

"The facts and inferences outlined above are summarized in the following table:
<table>
<thead>
<tr>
<th><strong>-- TIME --</strong></th>
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<td>Igneous intrusion</td>
<td>Deformation of Hong Kong granite</td>
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<tr>
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<td>Mountain building</td>
<td>Rejuvenation</td>
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<td>Mountain building</td>
<td>Deformation of Older Rocks and Structures</td>
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<td>Lower</td>
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<tr>
<td>Jurassic</td>
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<td>Repulse Bay volcanics</td>
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Tolo Channel formation
CHAPTER III

-- PETROGRAPHY --

Summary of the Igneous Geology of Hong Kong

The distribution of the igneous rocks of China, as conceived by Iddings, is shown in Figure I. He states, "Throughout China the characteristic rocks are granites, diorites and gabbros with porphyries and some lavas of the same composition. Nephelite syenite has been found on the Yangtze River near Kienchwan and nephelite-basalt at Yangshan, west of Weihsien. Nephelite basalt also occurs in Manchuria, northeast of Mukden. Granites and granodiorites with diorite and gabbro with corresponding lavas characterize the Lia Tung Peninsula and Chosen (Korea)."

The igneous rocks from the colony of Hong Kong vary from granites to granodiorites in composition and exhibit the volcanic, hypabyssal and plutonic phases. The oldest rocks are sediments and consist of conglomerates, sandstones and argillites exposed as remnants in the north-west half of the territory. They are referred to the Lower Jurassic, Lower Lias, Coroniceratan.

The Repulse Bay Volcanics lie unconformably on the Tolo Channel sediments. They consist of acid lavas, quartz-

(1) Dr. Uglow calls this formation the "Volcanic Sediments" in his field notes.
The extrusion of the Repulse Bay Volcanics was accompanied by the intrusion of rocks, sills and dykes. The intrusives vary from quartz-porphyries to granite-porphyries and are known as the Tai Mo Shan series.

The Taitam formation is a porphyritic hornblende-granite, which cuts all the above rocks. (1)

The Taitam formation is cut by the Hong Kong granite which is an even, coarse-grained, pinkish grey granitic rock, but near its contacts it becomes fine grained. It is cut by aplite and pegmatite dykes that also invade the neighboring rocks.

The last important intrusion is that of the Tan Tau granite porphyry which is a pink or pearl grey, highly felspathic rock, the dominant constituent being large felspar phenocrysts. Quartz, when present, is inclined to be idiomorphic, as is the sparse biotite. The rock varies in composition from a granite to a granodiorite and in texture from a granite-porphyry to a porphyritic granite. It cuts the Hong Kong granite against which it has a broad, strongly marked contact facies.

(1) No specimens or field descriptions of this formation were available from Dr. Uglow's map area and it has therefore been omitted. It is equivalent to the D'Aguilar Peak formation of Dr. Schofield.
Dark grey to black lamprophyre dykes cut all the previous rocks. They are probably differentiation products of the Tan Tau magma and constitute the last phase of the igneous activity in the district.

There are two rock groups whose relative ages have not been sufficiently established to place them in the above sequence of rocks. The Rocky Harbour Volcanics consist of elongated pink feldspar and quartz phenocrysts in a reddish to dark aphanitic groundmass. They are in the main acid volcanics.

The Junk Bay formation consists of a basal conglomerate, containing pebbles of the Repulse Bay Volcanics, with a siliceous and tuffaceous cement overlain by a series of tuffaceous sandstones with a few layers of siliceous argillites. The Rocky Harbour Volcanics overlie the Junk Bay formation.

(1) No specimens available.

(2) "Petrography of Rocks of the Crown Colony of Hong Kong" by Mr. N. F. C. Davis, Pages 22 - 25.

(3) "Petrography of Rocks of the Crown Colony of Hong Kong" by Mr. N. F. C. Davis, Pages 18 - 23.
— The Tolo Channel Series —

Distribution

Broadly speaking, there are three areas where the Tolo Channel series is exposed. On the south-west shore of Lan Tau island the series outcrops from Tai O to Sha Lo Wan, a distance of approximately 4.5 miles. The width of the exposure varies from 2 to 5 miles. The strike of the beds is N 30 E., and they dip at a high angle to the south-east.

Continuing along the strike of the Tolo Channel series on Lan Tau island the beds are found to outcrop on the mainland about 7 miles distant at Castle Peak Bay. The series extends north-east for about 8 miles and varies in width from 14 miles to 0.5 miles. That part which lies in the Shap Heung valley outcrops only as isolated patches in the clay deposits. The strike of the beds in this area is about N 30 E. The dip at Castle Peak Bay is south-east at a high angle while at the most north-westerly exposure the dip is to the north-west at a high angle. This sedimentary series occurs on The Brothers between Lan Tau island and Castle Peak bay.

The third area of sedimentary rocks occurs in the vicinity of Tolo Channel and Tolo Harbour, where the out-
crops represent isolated patches along the shores of the harbour.

**Lithology**

Within the area examined by Dr. Uglow, the Tolo Channel series consists of a basal group of conglomeratic, quartzose, rocks followed by thinly bedded layers of brownish, quartzitic, sandstone with interbeds of sandy, greyish, shale. Argillaceous sandstone, shaly sandstone, shale and some fine breccia are encountered at different horizons in the series. Many of the exposures show a highly fluted weathering. In the vicinity of igneous intrusions these sediments exhibit the effects of metamorphism. At Castle Peak bay on the mainland, occurs a slightly contorted metargillite, which is charged with nodules of epidote. One thin section, IV 44, was taken within 100 feet of the contact between the Tolo Channel series and the Hong Kong granite. The rock is a greyish, fresh, sericitic quartzite.

A large number of specimens collected by Dr. Schofield (1) were examined by Mr. N. F. G. Davis. His conclusions are quoted here.

"The conglomerates of this group which were studied in thin section are all more or less tuffaceous in nature. Many of them are what might be referred to as non-contemporaneous tuffs and may be called volcanic conglomerates. The

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(1) Mr. N. F. Davis "The Petrography of the Rocks of the Crown Colony of Hong Kong," Pages 9 - 10.
origin and nature of their primary constituents as apparently igneous, but they are related to exogenic rocks by the process of their deposition and by their occurrence in beds intercalated with ordinary sediments. The fragments in many cases have a rolled appearance, but some also show igneous origin by their irregular outline, in some cases showing embayed borders. In them are found minerals which do not ordinarily withstand the weathering which they would be subjected to in the formation of ordinary detrital sediments which points partly to their tuffaceous nature and partly to an extremely short transportation."

In the tuffaceous conglomerates quartz occurs as fragments of various sizes, some of which show embayed borders, while others show shadowy extinction indicating shearing stress. Orthoclase and plagioclase felspar, showing corrosion, are present, but they are much altered to calcite. Biotite occurs as light brown to reddish brown pleochroic flakes, scattered in between the large quartzes and felspars. Grains of magnetite and a few prisms of apatite are present.

The sandstones of the series exhibit transitional phases from the tuffaceous conglomerates through tuffaceous sandstones to the more finely compacted sandstones; in some cases almost quartzites. Quartz containing fluid cavities
and rutile or apatite inclusions, indicating a plutonic origin, is represented as rounded grains of varying sizes. A few grains of orthoclase and oligoclase are seen. A considerable amount of brown, pleochroic biotite is present with a little magnetite and some zircon. In some sections the quartz grains have been shattered and some muscovite is developed.

(1) Mr. N. F. C. Davis suggests that the presence of biotite indicates that the minerals have had but little transportation. Since the Tolo Channel series has been intruded by igneous rocks and subjected to mountain building forces since its deposition, it is not unreasonable to expect to find evidences of both dynamic and thermal metamorphism in the thin sections of the rock. The strain shadows shown in the quartz grains, the breaking of the crystals, and the alteration of the feldspars all indicate shearing stress.

(2) In discussing thermal metamorphism, Harker states, "Where a quartzose sandstone or grit has contained scattered decomposition products, such as kaolin, calcite and chlorite minerals, in small quantity, metamorphism produces a quartzite with granules of some accessory mineral. Thus, near the Shap granite, the grits in the Coniston Flags group have been transported into a quartzite with granules of colourless...

(2) Harker, Alfred, "Petrology for Students"Page 295, & 322
mica at the expense of alkali-feldspars. A characteristic alteration in the soda-lime-feldspar results in the minutely granular aggregate which has been called 'Susserite' and is not always of precisely the same nature."

The field relations of the Tolo Channel series strengthen the possibility that the presence of altered feldspar and biotite is due to thermal and dynamic metamorphism.

Metamorphism

The Tolo Channel series of sedimentary rocks shows the effects of thermal metamorphism at its contact with the Hong Kong granite and the Tai Mo Shan porphyry. In some cases, changes in the mineralogical composition of the rock have been induced through contact with the intrusive plutonic rocks while in a heated condition. These intrusions were accompanied by the emission of heated gases, vapours and water; and some of these agencies passed into the invaded rocks and often developed new minerals in them.

No hand specimens of thin sections which had been chosen to illustrate the thermal metamorphism of the Tolo Channel series were available so that it is only possible to briefly mention a few evidences of alteration which were noticed by Dr. Uglow in the field.

Within the contact aureole, the following minerals were developed: quartz, muscovite, epidote, garnet and
tourmaline. In some instances the sandstones are altered to quartzite or sericitic quartzite. The quartzite is sometimes full of quartz veinlets given off from the Hong Kong granite. (1) At IV 37, the argillite is altered and contorted a little and is charged with nodules of epidote. At VII 28, the Hong Kong granite is in contact with the sandstone and argillite of the Tolo Channel series. A narrow belt, 20 feet wide, against the granite, is altered to solid garnet, epidote and magnetite. In one instance a fine-grained felsitic phase of the granite, which may be a chilled margin, occurs at the contact with the sandstone.

From the contact phenomena described above, it appears that the alteration of the sandstone at the contact in due to thermal metamorphism and metasomatism.

Structural Relations

The Cordilleran trend in the vicinity of Hong Kong is north-east. The axis of folding in the Tolo Channel series roughly follows this orientation.

The Tolo Channel series which outcrops on the south west shore of Lan Tau island is the limb of an anticline whose axis trends N 31 E. The dip of the beds varies from 35 - 85 S.E. and they underly the volcanic sediments which

(1) The numerals refer to the main areal divisions of the geological map and the small numbers to the individual exposures.
are exposed to the east. A small synclinal trough occurs at VII 88, 90, 91.

The area of this sedimentary series on the mainland appears to be the continuation of the structure occurring on Lan Tau island. The beds exposed at Castle Rock bay form the eastern limb of an anticline whose axis trends N 31 E., while about 6 miles north along the strike, the western limb of an anticline is revealed.

The rocks constituting The Brothers islands between Lan Tau island and the Mainland comprise part of a syncline which plunges to the north-east.

There are some local disturbances of the beds due to the intrusion of the Tai Mo Shan group and the Hong Kong granite.

The Tolo Channel series is overlain by the Volcanic Sediments (Repulse Bay Volcanics) on Lan Tau island. An angular unconformity is evidenced near Tai O. The series is cut by the Tai Mo Shan porphyry and the Hong Kong granite.

The deformation and folding of the Tolo Channel series occurred during the period of instability which lasted from Jurassic to Miocene times.

(2) Age

"Fossils (ammonites) found by Dr. Hesnley of Hong Kong"

(1) See large map in pocket.

(2) Dr. Brock and Dr. Schofield "The Geology of the Crown Colony of Hong Kong."
Kong were examined by Dr. Grabau of Peking, who suggested a Lower Cretaceous age for these Tolo rocks, but better material collected by Dr. M. Y. Williams in the course of the present geological survey of the territory has enabled J. J. Buckman to determine the age definitely. It proves to be Lower Jurassic, Lower Lias, Coroniceratan. These are the only rocks whose age has been definitely fixed by fossil evidence."
--The Volcanic Sediments--
(Repulse Bay Volcanics)

Distribution

Within the area examined by Dr. Uglow, the principal occurrence of the formation known as the Repulse Bay Volcanics is on the south-west portion of Lantau Island. The outcrops constitute perhaps one-quarter of the area of the island. The flat lying attitude of the volcanic series is responsible for the position of the plateau between localities VII 100-104 and X 32, where its thickness can be estimated by the fact that it also occupies the bottoms of the valleys down to Shan Wat. The series is also especially well exposed in the valleys south of Tai O, around X 104-109 and along the south shore.

Lithology

The formation consists mainly of volcanic sediments with some closely associated felsites and quartz-porphyries. The bedded volcanics are chiefly quartzose tuffs varying from fine-bedded ash, gritty ash, thinly bedded chert-like tuff, tuff breccias, breccias and tuffaceous agglomerate. In color they are chiefly greyish to reddish depending on the number of phenocrysts of quartz and altered felspar which are present. The groundmass varies from a cryptocrystalline

(1) See Figure 3
texture to a microcrystalline mosaic of quartz and felspar. Magnetite and goethite are accessory.

From a study of five thin sections it is concluded that the rocks are quartzose tuffs. Microscopically, numerous angular and rounded phenocrysts of quartz and felspar are present. Of the quartz, some show embayed borders, while many of the smaller grains show crystal outlines. This is interpreted as evidence of devitrification. Around some of the quartz phenocrysts, which often contain rutile needles, is a narrow cloudy rim full of small particles of dark material whose nature is indeterminable. This seems to indicate that a reaction took place between the quartz and the groundmass. The felspar phenocrysts are altered to white mica. A microcrystalline mosaic of quartz and felspar makes up the groundmass, in which small amounts of magnetite and goethite are seen.

Structural Relations

The volcanic series is essentially flat, undulating a little, but not showing any particular tendency to follow the cordilleran trend. The lavas show flow structure which is accentuated by the weathering of the rocks.

The exact contact of the Tolo Channel series and the Volcanic Sediments (Repulse Bay Volcanics) is not exposed.

(1) See Plate 9
but the typical buff sandstone, weathering reddish, with rounded surfaces is well shown at VII 90 in contact with the quartz-crystal-tuff of the Volcanic series. The Tolo Channel series is much deformed and the dip and strike of the beds vary.

There is without doubt a structural discordance and unconformity between the two series. The lava flows and associated volcanic sediments lie in a generally flat attitude but folded slightly along the axis trending N 60 E. The flows along the northern slopes of the island usually dip from 10 to 30 N. W., while it is expected that those along the south side dip to the south-east. The Tai Mo Shan porphyry has arched the series of volcanics into an anticline. It is impossible to differentiate the flows from the sediments in mapping on account of the nearly flat attitude of both. Strikes and dips of the series are indicated on the map where observed.

There is apparently an angular unconformity between the volcanic series and the Tolo Channel sediments along the north shore of Tan Tau island. Cliffs and ridges south of Nan Chung and Tai O are underlain by nearly flat-lying gritty tuff, with vertical jointing. This is well observed from Tai O harbour, where the series is at least 900 feet thick and overlies the Tolo Channel sandstone of Tai O island uncon-
formably but the relation of the intrusive porphyry to the volcanic series is not evident.

Near X 93, the Tai Mo Shan porphyry may be observed to lap across the bevelled edges of an underlying series of argillites and sandy tuff that dip about 30° E. These are believed to belong to the volcanic sedimentary series.

**Age**

It is suggested by Dr. Brock and Dr. Schofield that the age of the Repulse Bay Volcanics may be Upper Jurassic.

**Conclusions**

The Repulse Bay Volcanics were derived from a very acid magma. The extrusion of the material was the beginning of the igneous cycle which is represented by the rocks of the Hong Kong petrographic province. This period of vulcanism might be said to be the prelude to the igneous activity which accompanied the great crust movements along the borders of the Pacific during the Jurassic and Tertiary times.
---Tai Mo Shan Porphyry---

**Distribution**

The Tai Mo Shan porphyry is exposed as isolated outcrops along the south-east shores of Lan Tau island. A sill-like body extends completely across the south-west portion of the island. This exposure is about 5 miles in width and 3 miles in length. A large area of this rock occurs in the central portion of the island. Small outcrops are exposed on the north of Lan Tau island and on Tsing I island. On the mainland the Tai Mo Shan porphyry stretches from Yau Kam Tau north-east to Tolo Harbour. The width of this outcrop is about 8 miles, but it is divided by a narrow tongue of Lan Tau porphyry. A smaller patch is found to the west.

**Lithology**

The Tai Mo Shan porphyry is the stratigraphic name applied to a group of rocks varying from granites to ademellite in composition. All the specimens examined are too high in plagioclase (andesine) to be termed normal granites, while some of the specimens classed as ademellites show a strong granodioritic tendency.

The texture of these rocks ranges from porphyritic to granitic. The porphyritic character is often strikingly

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(1.) See Figure 4
brought out by weathering.

The color of the Tai Ho Shan porphyry varies from a light grey to a dark grey or greenish hue.

--Microscopical Description--

Phenocrysts

The most abundant phenocryst is felspar, which includes both alkali and alkali-lime varieties. Of the alkali series, orthoclase and microcline are most abundant, but in some cases a microperthitic intergrowth of orthoclase and albite is present. Carlsbad twinning is very common. The alteration of the alkali felspar produces a fine, dense, greyish-brown substance which may be kaolin, but the individual particles are much too small to allow of any conclusive optical test. The alkali-lime felspar varies from oligoclase to andesine. The crystals frequently show a marked zonary banding between crossed nicols and twin-lamellation on the albite type is developed. Unlike the orthoclase, the alteration products of the plagioclase are of sufficient coarseness to be determined by optical tests. They are epidote, white mica, calcite and quartz.

The mineral next in abundance to felspar is quartz in angular fragments or corroded phenocrysts. They are remarkable for their undulatory extinction and the cracks by which strain has been relieved. Some of the phenocrysts are almost
completely reduced to granules which do not show strain shadows.

The crystals of brown or greenish pleochroic biotite are in tabular plates or laths, which sometimes show twinning. Occasionally some granular augite is developed. The alteration of the ferromagnesian minerals is to epidote and chlorite. Apatite and magnetite are common accessories, accompanied in some cases by zircon and garnet.

Groundmass

The microcrystalline groundmass of the Tai Mo Shan porphyry consists of a clear mosaic of quartz and felspar. In some instances, the quartz grains have a feathery appearance at the edges, which may be attributed to recrystallization. The directive character which the groundmass occasionally exhibits is due to the alignment of small flakes of white mica.

---The Granite Phase---

The granite phase of the Tai Mo Shan series is light grey in color and hypidiomorphic granular in texture. Orthoclase is the dominant felspar occurring as phenocrysts and in the groundmass. In a few cases a microperthitic intergrowth of orthoclase and albite is developed, while andesine is represented by a few large grains. Small grains of quartz between the laths of felspar make up a large

(1) See Plate 5
percentage of the rock. A pale, greenish, pleochroic biotite, which is greatly altered to chlorite is present in small amounts.

---Basic Phase---

In the dark grey phase of granite-porphyry texture large phenocrysts of oligoclase occur with a few small phenocrysts of orthoclase and quartz. The oligoclase is altered to white mica and epidote, while the orthoclase has the usual dense cloudy material, possibly kaolin. The ferromagnesian minerals are biotite and hornblende, largely altered to epidote and iron ore. The groundmass is a microcrystalline mosaic of quartz and felspar.

---Quartz-Felspar-Porphyry Phase---

At Locality VII 75, this type is massive, not laminated and weathers into sub-angular boulders of dull maroon surface. Microscopically, the texture of the rock is porphyritic. The phenocrysts are orthoclase, showing some microperthitic intergrowth. Andesine and quartz in a microcrystalline groundmass of quartz, orthoclase and frequently much white mica. The andesine is chiefly altered to white mica and the orthoclase to a cloudy substance, possibly kaolin. The quartz phenocrysts have smooth corroded outlines or angular edges. The quartz

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(1) See Plate 10
granules in the groundmass exhibit a feathery margin which may be due to the process of recrystallization. No data on this point was found in the literature. The ferromagnesian minerals, biotite and hornblende, are chiefly altered to epidote and chlorite. Magnetite is accessory.

The composition of the quartz-felspar-porphyry phase does not agree with that of a normal dacite, but seems to be intermediate between a latite and a dacite. The magma from which these rocks were derived had a composition corresponding to adamellite rather than a true granite or granodiorite.

Effects of Shearing Stress

Most of the thin sections examined showed evidence that the rock had been subjected to shearing stress which may have been applied under two conditions. In some instances phenocrysts of quartz and of ferromagnesian minerals are broken and there is no sign of the groundmass being subjected to shearing stress. The phenocrysts may have been broken when the rock was in motion as a pasty mass. The second condition is when the phenocrysts of quartz and felspar are broken and much white mica, showing a definite alignment, is developed in the groundmass. This may indicate that the rock was subjected to shearing stress after it had solidified.

(1) See Plate 1
The effect of shearing stress on the quartz phenocrysts was well illustrated in a number of cases. The crystal first shows strain shadows, but as the stress is progressively increased numerous cracks develop and the stress is finally relieved by the granulation of the crystal. The resultant grains do not show strain shadows, and in some cases flow into cracks developed in felspar phenocrysts.

It is thought that the alteration of the felspar laths to white mica is the result of shearing stress as it was noticed that white mica was developed under stress.

The above effects have been described by Harker in his discussion of metamorphism and have been recognized by many other workers in this field, but in the North American literature, at least, there appears to be few detailed discussions of such phenomena. The American occurrence which shows almost similar effects of shearing stress is described by Florence Bascom. The quartz porphyries of South Mountain, Pennsylvania, differ from the Tai Mo Shan porphyries, however, in that the felspars are remarkably fresh and unaltered, and there is proof of devitrification having occurred in the groundmass.

(1) See Plate 1
(2) Harker, Alfred "Petrology for Students" Pages 320 - 324
Metamorphism

In the field there are many evidences that the Tai Mo Shan rocks have suffered thermal and dynamic metamorphism. (1)

These effects, described by Dr. Uglow, are given below.

At locality V 12, a deep excavation exposes a pink rock which is highly altered and bleached. A banded quartz vein 4 feet wide and other veins up to 3 feet wide have a strike of 180°. The softening and bleaching of the Tai Mo Shan porphyry is probably due to the action of these silicious solution.

Near the contact of the Hong Kong granite and the Tai Mo Shan porphyry at locality V 14, there is a narrow belt, trending parallel to the contact, of what appears to be white sericite schist, probably a contact phase between the two rocks. The contact metamorphism was due to the intrusion of the Hong Kong granite. Very likely the quartz stringers are genetically related to the granite, particularly as they trend normal to the contact. The accompanying sericitization of the Tai Mo Shan porphyry might explain the deep weathering of the rock exposures.

At locality V 87, a tunnel 50 feet long is driven on the contact of the Tai Mo Shan porphyry and a basic phase of the Hong Kong granite. Some garnet and epidote occur in the Tai Mo Shan porphyry.

(1) Uglow, W. L. From Field Notes
At locality V 99, the Tai Mo Shan porphyry is sheared or foliated with a trend N 65-70 E., and the rock resembles a quartz-sericite-schist.

At V 135, a small prospect tunnel is driven on an E-W shear zone in the Tai Mo Shan porphyry, near its contact with a tongue of Hong Kong granite. This shear zone, which contains small amounts of magnetite, is chloritized and soft.

From V 176 - 179 the Tai Mo Shan porphyry is full of rock fragments, nests of epidote and generally shows the effects of contact metamorphism.

It appears that the alteration which is so apparent in the Tai Mo Shan series has been due to a number of causes. The phenocrysts developed were broken in many cases while the rock was in movement as a pasty mass. After the rock had solidified there was a period of mountain building accompanied by igneous intrusion and the series was acted upon by the forces of both thermal and dynamic metamorphism.

Structural Relations

From X 97 to X 107 the nearly flat lying volcanic sediments dip from 10 E to 20 E and appear to dip under the tabular body of Tai Mo Shan porphyry to the east.

At X 93 the Tai Mo Shan porphyry may be observed at low tide to lap across the bevelled edges of an underlying.
series of argillites and sandy tuff that dip about S 30 E and are believed to belong to the volcanic sedimentary series.

Near X 92 the volcanic sediments are separated from The Tai Mo Shan porphyry by a well-marked, normal fault, that crosses a hill and is weathered out into a rocky depression. The beds of the volcanic sediments bend upwards at the fault to a dip of 80 indicating that they have been downfaulted. The body outlined as Tai Mo Shan porphyry in this vicinity is mainly a sheeted, quartz-felspar-porphyry that is believed to have been injected into the volcanic sediments nearly concordantly. It does not show contact metamorphic effects or any of the features of lava flows. It is believed to be the sill injection variety of the Tai Mo Shan porphyry just as the Tai Mo Shan peak type is a plug or neck variety and other granitoid types are dyke varieties.

In the vicinity of X 35 a continuous felsite and tuff is intruded by a lenticular shaped body of rhyolite porphyry which is an apophysis of the Tai Mo Shan porphyry from Lan Tau peak.

At Keyng Shan, an irregularly shaped body of Tai Mo Shan porphyry is exposed. This is believed to be a sill emanating from the main body at Lan Tau Shan and passing underneath the ridges to the west to appear again on the shore at X 27 - X 32.
At locality X 46 - 47 the Tai Mo Shan rock seems to be a nearly flat lying sill in the volcanic sediments; it is syenitic above and granitic below.

The rhyolite porphyry, included as a part of the Tai Mo Shan series, is believed to be mainly dyke and sill injections of viscous, acidic lava, which through movement developed flow structure. The somewhat polygonal outlines of this porphyry against the Volcanic series (Repulse Bay Volcanics) is believed to be due to block faulting of the series after injection by the rhyolite porphyry.

From the structural relations it is concluded that the Tai Mo Shan porphyry is a sill and dyke phase of the igneous body of which the Volcanic Sediments represent the extrusive phase.

**Age**

The age of the Tai Mo Shan porphyry is placed as Upper Jurassic by Dr. Schofield and Dr. Brock. The series was folded and faulted during the Jurassic Revolution.
Sketch to Indicate the Distribution of the Formations.

Legend:
- Lan Tau Br.
- Hong Kong Granites
- Ter. M. Shan Br.
- Volcanic Sediments
- Tolo Channel Series

Figure 5
--Hong Kong Granite--

**Distribution**

1. The Hong Kong granite is part of a huge batholith, extending from Hong Kong to Ning Po, which is comparable in size to the Coast Range batholith of British Columbia.

In the map area the granite is exposed in many localities for variable distances, but apparently has not been unroofed as long as the Coast Range batholith, since the surface between the isolated outcrops are composed of older rocks and represent roof pendants which have not yet been eroded.

On the mainland, north of Hong Kong island, the Hong Kong granite is exposed from the vicinity of Tyee Mun Pass along the shore of Kowloon bay and north-east to Gin Drinkers bay. This exposure continues in a north-east direction to Tide cove. To the west the granite again outcrops on the shore at Ting Kau and extends to Castle Peak bay. This outcrop continues inland for about 4 miles. West of Castle Peak bay the Hong Kong granite is found along the shore of the peninsula to the Hong Miau, a distance of 11 miles. The eastern boundary of this exposure is roughly a straight line joining VII 71 and IV 54.

To the west of this body on the mainland lie Tong

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(1) See Figure 5
Ku island and San Chan island, wholly composed of granite.

A small area of granite is exposed on the west shore of Lan Tau island from She Tsin Tau westward 2.5 miles with a width of about 1 mile.

On the south-east side of Lan Tau island the granite occupies a small peninsula and Ch' eung Chau island. The south-east half of Ni Ku Chau island is made up of Hong Kong granite, while small exposures of granite occur on the north-east end of Lan Tau island and on Ma Wan island and Tsing I island.

Lithology

The typical Hong Kong granite is coarse-grained, holocrystalline, equigranular and light pinkish in color. There are, however, many modifications to finer-grained and darker-coloured varieties.

Dr. Brock states, "Due to its mode of weathering as well as its abundance, it is much the most conspicuous rock. It is normally an even, coarse-grained, pinkish, grey, biotite granite, but near its contact it becomes fine-grained. It is cut by aplite and pegmatite dykes that also invade the neighboring rocks. The pegmatites have given origin to quartz veins particularly in the granite itself, containing wolframite tinstone and molybdenite."

For field purposes this rock group was termed a
granite. A study of the thin sections, however, revealed the fact that the mineralogical composition varies from a granite to a granodiorite. Of the specimens classed as granites, all were found to be too high in plagioclase to be called normal granites.

The texture varies from porphyritic to granitic and almost aphanitic.

Those specimens which tend towards granite in composition are light grey or pinkish in color, while those which have more the composition of granodiorite are dark grey.

Mineralogical Characters

Quartz is seldom idiomorphic, except where enclosed by microcline and frequently shows inclusions of rutile needles. The dominant felspar is usually orthoclase, in which Carlsbad twinning is common and the alteration is to a fine, dense, cloudy material which may be kaolin. Microcline is quite frequently seen and is abundant in some specimens. The plagioclase felspar is oligoclase or andesine and the alteration is to white mica and epidote. Brown, pleochroic biotite is common and green hornblende occurs, while minor amounts of granular augite are sometimes present. Apatite is a common accessory, with zircon, garnet and magnetite. Micrographic intergrowths are often seen.
---The Fine-Grained Phase---

Microscopically, the fine-grained phase of the series consists of minor numbers of phenocrysts of quartz, orthoclase and plagioclase (andesine). Some microperthitic intergrowth of orthoclase and albite occurs. The groundmass is usually a microcrystalline mosaic of quartz, orthoclase and plagioclase. Ferromagnesian minerals are generally absent. Very little micrographic intergrowth is seen as a rule but one specimen proved to be a granophyre, being almost completely composed of an intergrowth of orthoclase and quartz.

---The Granite Phase---

In the hand specimen the granite phase of the series is pinkish in color. The texture is coarse-grained and in some cases gneissic banding is shown.

A thin section of such a gneissic specimen was examined, and it was found that the quartz phenocrysts show (1) the effects of shearing stress. Many large phenocrysts have been broken into a great number of closely compacted granules. The large fragments which have not relieved the stress by breaking, show strain shadows, but the small grains do not show these optical anomalies. In some cases the small granules of quartz appear to have penetrated cracks in the

(1) Plate 5 illustrates similar stress effects in the Tai Mo Shan rocks.
felspar. The felspares are orthoclase, showing a great deal of microperthitic intergrowth, and oligoclase. Some anorthoclase was noticed. The felspares show two distinct alterations. The first is to a dense, brownish substance, which may be kaolin and superimposed on this is a second alteration to white mica. The ferromagnesian minerals are completely altered to chlorite. This type of granite is an example of a strong or highly rigid rock subjected to shearing stress. In this case the stress is relieved by the individual minerals breaking and altering while the rock as a whole remains rigid. The felspar under shearing stress has altered to white mica. The first, brownish alteration may have been due to pneumatolytic processes.

---The Ademellite Phase---

The ademellite phase of the Hong Kong granite is pinkish in color and has a hypidiomorphic texture. It is distinguished from the granite type in the hand specimen by the larger percentage of creamy to greenish colored plagioclase which is in contrast to the pink orthoclase. The plagioclase is andesine and it is frequently altered to white mica and epidote. The ferromagnesian minerals are pale, yellowish-brown, biotite and hornblende altering to epidote and chlorite.

---Granodiorite Phase---

The granodiorite variety is a greyish rock which
has a larger percentage of ferromagnesian minerals than is found in the previous types. Amphibole, altering to white micas and epidote is the dominant felspar, but orthoclase is present in subordinate amounts. Large phenocrysts of quartz which show the effects of strain are present. The ferromagnesian minerals are almost completely altered to chlorite. Some colorless to greenish-brown flakes of biotite (1) occur, which have bent under shearing stress. Ilmenite, surrounded by a border of sphene, is present.

**Contact Phenomena**

In many instances a fine-grained, felsitic phase of the granite lies against the sediments which it intruded. This appears to be a cooled or chilled margin. At locality (2) IV 42, the marginal phase of the Hong Kong granite is strongly foliated close to the contact with the sediments.

In the contact zone occur granite-porphyry, complementary dykes and knots of pegmatite. These appear to be differentiates of the main body of Hong Kong granite.

**Structural Relations**

Apart from a little minor faulting and sheeting, the Hong Kong granite shows no evidence of disturbance except in the north-west. Here it has been deformed to gneiss.

In the field this series is seen to intrude the Tolo Channel

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(1) Plate 2 shows a similar case noticed in the Tai Wo Shan porphyry.
(2) See Plate 8
series, the Volcanic series and the Tai Mo Shan prophyry. The Hong Kong granite is cut by the Lan Tau porphyry.

Age

Dr. Schofield and Dr. Brock believe the intrusion took place during the Laramide Revolution.

The intrusion of the Hong Kong batholith marked the height of the igneous activity which, acting with the contemporaneous mountain building, tended to relieve the accumulated stresses in the earth's crust along the south-east coast of China.
MINERALOGICAL COMPOSITION
OF
HONG KONG GRANITE

Planimeter Method

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Granite

Granite

Ademellite

Ademellite
The Lan Tau Porphyry --

Distribution

The Lan Tau porphyry is exposed on the most south-westerly tip of Lan Tau island and on a small peninsula three miles to the west. The islands fringing the south-east shore of Lan Tau island are composed wholly or in part of Lan Tau porphyry. The rock constitutes the north-east half of Lan Tau island and over half the area of Tsing I island. On the mainland, a narrow tongue extends from the shore at Tsuan Wan north-east, a distance of about 4 miles. The average width of this exposure is .3 miles. On the shores of Tolo Channel the Lan Tau porphyry is exposed at Tai Po Market and extends south-west for 6.4 miles with an average width of .6 miles.

Lithology

The Lan Tau porphyry varies in color from pink to dark grey. In composition, the rock varies from a granite to a granodiorite, while the texture varies from a quartz-felspar-porphyry to a porphyritic granite. The rock is highly weathered on the surface and the phenocrysts of felspar and quartz stand out in relief in the granite porphyry phases.

(1) See Figure 6
--Porphyritic Phase--

The porphyritic variety of the Lan Tau series is designated a quartz-felspar-porphyry. Megascopically, the rock is pinkish in color, with small phenocrysts of orthoclase and quartz in a dense matrix. In the thin section, phenocrysts of quartz, orthoclase and plagioclase occur in a microcrystalline mosaic of quartz and felspar. Considerable micrographic intergrowth is frequently present in the groundmass. The quartz phenocrysts are generally corroded. The felspars are altered to white mica and epidote, while the ferromagnesian minerals are frequently almost completely altered to chlorite and epidote. Apatite and magnetite are accessory.

--Granite Phase--

One phase of the Lan Tau porphyry approximates granite in composition. The rock is flesh pink in color and hypidiomorphic granular in texture. Quartz constitutes about 10% of the rock, but occurs as small grains between the felspar crystals. For this reason it is not noticeable in the hand specimen and in the field the rock has monzonitic character. The chief felspars are orthoclase and microcline. A small percentage of andesine is present. Orthoclase and microcline are altered to a fine, dense, cloudy material. The andesine is altered to white mica and epidote.
The ferromagnesian minerals occur in minor amounts, but they generally alter to chlorite and epidote. Some altered biotite with prisms of apatite in it occur.

---Ademellite Phase---

The ademellite type is a porphyritic rock of pale flesh-red color. Flesh-red phenocrysts of orthoclase up to .75 inches long, showing Carlsbad twinning, with some white felspar occur in a medium-grained matrix of hornblende, felspar and quartz. The orthoclase is almost completely altered to a fine, dense, cloudy material and forms a large percentage of the rock. The plagioclase felspar is andesine which is altered to white mica. Quartz is present in small grains between the felspars and in the groundmass. Hornblende and biotite are present in minor amounts and show alteration to chlorite and epidote. Apatite and magnetite are accessory. The term ademellite is applied to this rock because it contains too much plagioclase for a normal granite and too much quartz for a normal syenite. It is intermediate in composition between a granite and a granodiorite.

---Granodiorite Phase---

The granodiorite phase of the Lan Tau is pinkish grey to dark grey in color. The texture varies from granitic to porphyritic. The ratio of orthoclase to plagioclase felspar corresponds fairly closely with that given by
Lindgren in his description of granodiorite.

A large percentage of quartz is present as sub-hedral grains. Large phenocrysts of andesine largely altered to white mica are present. Orthoclase is noticed in minor amounts and shows the usual cloudy alteration. Some microperthite is found. The ferromagnesian minerals are hornblende and biotite, altered to chlorite and epidote. The groundmass is generally a mosaic of quartz and orthoclase.

Some specimens seemed to have a little too much quartz and plagioclase to be normal granodiorites.

Contact Phenomena

At locality VII (1), in the ademellite phase of the Lan Tau rocks, quartz-felspar-pegmatite bundles and veinlets occur, accompanied by some glassy quartz veinlets. Galena and some sphalerite occur with these in the heart of the porphyry. The sulphides may be a phase of the pegmatic upper contact zone of the porphyry.

At VIII 8 quartz occurs in crustified veins with brownish rock fragments between the veinlets. This may be a replacement in sandstone, under contact conditions, from the Lan Tau porphyry.

At VIII 61 a small amount of galena is scattered through the Hong Kong granite near a small shear zone within

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(1) Lindgren, W. "Granodiorite and Other Intermediate Rocks" American Journal of Science, 4, Volume 9, 1900, Page 229
25 feet of where the Hong Kong granite is cut by the Lan Tau porphyry. Galena, sphalerite and chalcopyrite, all occur without any gangue, in seams in the Hong Kong granite and in pegmatite nests in it. The minerals appear to be related in origin to the pegmatite, which may have resulted from the intrusion of the Lan Tau porphyry in the general NE-SW zone of weakness.

**Structural Relations**

The structural trend of the region is north-east to south-west and the Lan Tau porphyry is a lenticular shaped mass with its long direction parallel to the structural direction. It cuts the Hong Kong granite against which it shows chilled margins. At many localities it cuts the Hong Kong granite in the form of dykes.

There is a multiple sill on the extreme south-west shore of Lan Tau island, which dips about N 30° E through the lavas and associated sediments. In the rentrant at X 47 the dip is well shown. The most north-east portion of the multiple sill is a granite porphyry with trachytic felspars oriented probably parallel to the contact. The next sill is a fine-grained granite which is mapped as Hong Kong granite. The most south-westerly sill is of Lan Tau porphyry.
It is probable that those sills as well as the intrusive body of X 14- X 19 are apophyses from a body of Lan Tau porphyry and are tabular bodies invading the volcanics.

From X 46 - 48 the rock appears to be a nearly flat-lying sill in the volcanics.

Age

The Lan Tau rocks have not been subjected to stress and their intrusion marked the last great disturbance in the vicinity of Hong Kong, possibly the Miocene Revolution.
MINERALOGICAL COMPOSITION

OF

LAN TAU PORPHYRY

Planimeter Method

<table>
<thead>
<tr>
<th>Sample</th>
<th>Plagioclase</th>
<th>Orthoclase</th>
<th>Quartz</th>
<th>Ferromagnesian minerals</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X 54</td>
<td>9.6%</td>
<td>74.4%</td>
<td>10.0%</td>
<td>6.0%</td>
<td>Granite</td>
</tr>
<tr>
<td>V D</td>
<td>46.7%</td>
<td>18.0%</td>
<td>29.0%</td>
<td>5.0%</td>
<td>Granodiorite</td>
</tr>
<tr>
<td>V 86</td>
<td>55.0%</td>
<td>17.0%</td>
<td>28.0%</td>
<td>8.0%</td>
<td>Granodiorite</td>
</tr>
<tr>
<td>X 15</td>
<td>17.0%</td>
<td>63.0%</td>
<td>18.0%</td>
<td>2.0%</td>
<td>Ademellite</td>
</tr>
<tr>
<td>V 37a</td>
<td>43.5%</td>
<td>15.0%</td>
<td>30.0%</td>
<td>10.4%</td>
<td>Granodiorite</td>
</tr>
</tbody>
</table>
CHAPTER IV

--SUMMARY AND CONCLUSIONS--

(1) According to Harker, the normal cycle in which igneous activity manifests itself is: (1) volcanic phase (2) plutonic phase, (3) minor intrusions. The rocks of the Hong Kong province are a good illustration of a complete cycle of igneous activity. The Volcanic sediments and the Tai Mo Shan porphyry constitute the volcanic phase. The Hong Kong granite and Lan Tau porphyry represent the plutonic phase, while the dykes which cut the Hong Kong granite and Lan Tau porphyry are the minor intrusions.

It appears that up to the close of Lower Jurassic time stresses had been accumulating in the earth's crust along a direction which corresponds to the present coast line of China. The accumulated stresses were relieved in two ways—by igneous intrusions, which the Hong Kong suite of rocks represent, and by crust movements of the mountain building type. The igneous activity began in the Upper Jurassic, reached its maximum development during the Laramide Revolution and died away at the close of Miocene time. From a chronological standpoint, the rocks of the Hong Kong province are assigned to the Tertiary period of activity.

(1) Harker, A. "Natural History of Igneous Rocks" Page 97, also see Figure 2
Limits of the Principal Part of the Pacific Petrographical Region for the Tertiary and Recent Igneous Rocks

From Harker's 'Natural History of Igneous Rocks' p. 97

Figure 7.
in contrast to the igneous rocks of Palaeozoic and pre-
Palaeozoic age.

(1) From a study of Harker's chart of the petrographic
regions we would expect that the rocks of the Hong Kong
province would have the general mineralogical characteristics
of the rocks of the Pacific region. These are:

(1) Alkali-feldspars, not abundant, except in
the more acid rocks and wanting in the basic,
soda lime feldspars abundant.

(2) Zonary banding of feldspars frequent.

(3) Felspathoid minerals not found.

(4) Quartz not only in acid rocks, but also
in many intermediate ones.

(5) Pyroxenes represented by augite, diopside,
and the rhombic group; amphiboles by common
hornblende.

(6) Mica not common except in the more acid
rocks.

The mineralogical composition of the rocks varies
from that corresponding to a granite to ademellite and granodiorite. Only one example of normal granite was studied,
the rest of the specimens classed as granite in the field,
being rather high in plagioclase to be typical examples of
that rock type. The dominant rock type appears to have the
composition of quartz monzonite and was called ademellite.

The plutonic rocks, i.e., the Hong Kong granite
and Lan Tau porphyry, are the crystallized equivalents of

(1) See Figure 7
large bodies of deep-seated magmas. These invaded the stratified Tolo Channel series, not in one advance probably, but by repeated advances of liquified rock. The Lan Tau rock cuts and sends forth apophyses into the Hong Kong granite. The intricate relationship between the successive intrusions (1) is shown in Tsing I island and on the north end of Lan Tau island.

There are many localities where the roof has been little more than removed, the plutonic rocks exposed at the surface being laden with fragments of the stratified series as truly as when they are in lateral contact with a roof remnant.

The close mineralogical relationship which these rocks bear to each other suggests that the different intrusive bodies were produced by the differentiation of a magma that must have been at least of homogeneous character.

One of the most interesting features of the rocks of the Hong Kong suite is the alteration of the felspars and ferro-magnesian minerals. This alteration was attributed by (2) Mr. N. F. G. Davis to the agencies of weathering. In many cases, however, it appears that the alteration may be due to thermal and dynamic metamorphism.

In comparing the Hong Kong batholith with the

(1) See map in pocket.
(2) Davis, N.F.G. "Petrography of Rocks of Hong Kong", Page 30
Coast Range batholith of British Columbia, Davis states—
"Hence its (Hong Kong batholith) more acid nature is what would be expected from the crystallization differentiation of a magma and its age." Davis believed the Hong Kong batholith to be granitic in composition, but all the specimens available show its distinct granodioritic tendencies. He also overlooked the fact that the Coast Range batholith is made up of a number of separate intrusions and in some cases it has the composition of granite. Along the fiords of the Coast Range, exposures of the batholith may be seen extending from sea level to altitudes of 8000 feet. Dr. Dolmage, in his study of the batholith, has found no regular gradation from acid to basic composition as a deeper part of the batholith is reached. It seems only possible to state that both of these batholiths belong to the Pacific Region of igneous rocks and hence have the same general mineralogical characters exhibited by all the rocks of this region.

(1) Dolmage, V. Personal communication
---LIST OF ILLUSTRATIONS---

The Biotite has broken under shearing stress but there is no sign of the groundmass having been subjected to a similar force.
A lath of biotite which has been slightly bent due to shearing stress.
A quartz phenocryst which has relieved the stress by cracking.
A shattered phenocryst of quartz showing some of the grains penetrating a crystal of felspar.
Section X 49. Tai Mo Shan Porphyrty.

In yielding to shearing stress the quartz phenocryst has first cracked and then broken into numerous small granules.
Section V 41. Tai Mo Shan Porphyry. x 60

The groundmass has assumed a definite alignment under shearing stress.
Plate 7

Section 5 95  Tai Mo Shan Porphyry.

x 60

Plate to illustrate the directive character of the groundmass
and the development of flakes of biotite around the phenocrysts
of quartz and felspar.
Section IV 42. X 264

Hong Kong Granite
(A marginal phase).

Illustration of a rock which has completely yielded to shearing stress and recrystallization of the minerals has taken place.
A hybrid zone, which could not be determined optically, existing around a quartz phenocryst.
PLATE 10

Hong Kong Granite

*Orthoclase*

Quartz

Micropegmatite. Intergrowth of Quartz and Orthoclase.