Vol. 7. No. 1 June 1952.

# THAI SCIENCE BULLETIN

DEPARTMENT OF SCIENCE
MINISTRY OF INDUSTRY
BANGKOK, THAILAND.

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**DEPARTMENT OF SCIENCE**

**Ministry of Industry, Bangkok, Thailand.**

*Director-General : Dr. Charng Ratanarat.*

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The Thai Science Bulletin is edited for the Department of Science, Ministry of Industry, Bangkok, Thailand.

It is intended to report the work in all branches of science of the Department and whenever possible those from other scientific institutes in the country.

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The Siam Science Bulletin was first published in 1937. The title was changed to Thai Science Bulletin since 1939. Its original purpose was to enable various Government Scientific Institutes and Laboratories to make known to other countries the results of their investigations. However contributions had been very scanty all along and the irregularity in issuing the Bulletin could be accounted for.

It is now hoped to publish the Bulletin six-monthly. Having been unable to fulfil our original intention, we propose as an alternative to make an abstract of some useful scientific articles which may appear in other publications in the country from this issue onwards.

*Charng Ratanarat.*

Chairman of the Editorial Board.

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**Department of Science,**
**Ministry of Industry, Bangkok, Thailand.**

**Vol. 7. No. 1.** **June 1952.**

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## ABSTRACTS.

# Hydrogenation of Volatile Oil Distilled from Gurjun Balsam.

**By Miss Priya Chandravekin, B. Sc.**

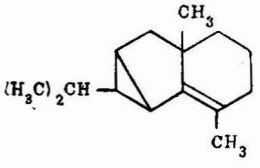
*Department of Science.*

Gurjun Balsam, tapped from the Yang trees (*Dipterocarpus alatus*), is a liquid consisting of volatile oils and resins. The balsam is also known in different localities as Wood oil or Garjun oil (India), Kanyin oil (Burma), Keruing oil (Malaya) and Balau resin (Philippine Islands). The colour varies from light brown to dark brown or dark green with a shade of fluorescence.

The general properties of the Balsam are as follows:- Specific Gravity 0.957 - 0.999; Optical Rotation - 22° — -77°; and Refractive Index 1.500 - 1.516. It is partially soluble in alcohol.

On steam distillation, it yields about 70%-80% volatile oil and the rest is resin. The volatile oil is yellow with the B.P. of 255° C. Specific Gravity 0.912 - 0.930; Optical Rotation - 350° — - 130°; and fractive Index 1.500 - 1.505.

The oil consists of two kinds of sesquiterpene, c. 67% laevo - rotatory, ∝ -gurjunene and c. 33% dextro - rotatory β -gurjunene. Both isomers are of tricyclic, cedrene type; the molecular formula is $C_{15}H_{24}$. According to Triebs (1935) the structural formula of ∝ —gurgunene is :—




The structure of β - gurjunene has not been proposed.

The residue from steam distillation is a mixture of gurjoresene, $C_{17}H_{28}O_2$, amorphous, M.P. 40-43 °C., and crystallisable gurjunic acid, $C_{44}H_{68}O_8$. They represent 16-18% and 3% of the gurjun balsam respectively.

The use of the volatile oil as fuel has long been practiced. But it has been a problem to keep the oil clear on standing. Excessive stickiness prevents its practical uses. The purpose of the investigation is to improve the fuel quality of the volatile oil by hydrogenation.

The investigation is only a preliminary one but good results have already been obtained.

Using Raney Nickel as catalyst, the hydrogenation is carried out in the high Pressure Hydrogenation Apparatus (Parr Instrument Co.). The Apparatus consists of a reaction bomb of a capacity of 480 ml., an electric heater to heat the bomb with an adjustable transformer, and a shaking mechanism with motor. Hydrogen is supplied from a pressure cylinder.

The Raney Nickel catalyst is an alloy of Ni and Al in the ratio of 1:1. This was ground into fine powder, and boiled in NaOH until no hydrogen was seen bubbling up. The powder was washed clean and kept in alcohol.

The volatile oil obtained from the distillation at 240 - 260 °C was about 73% by volume, It was yellow, but became darker on standing.

Two experiments were performed. In the first experiment, a pressure of 400 - 500 lbs./sq.in. at 80 - 100°C was employed, but in the second experiment, a pressure of about 1500 lbs./sq.in. at 120-140° C was used.

About 200 ml. of the volatile oil was put in the reaction bomb with about 10 g. of the catalyst and about 50 ml. of 90% alcohol. Hydrogen was supplied through connecting tubes from a cylinder until a pressure of about 500 lbs/sq. in. was obtained. The shaking mechanism was turned on to see whether the pressure would drop, if it does, more hydrogen has to be supplied. When the pressure was constant, the heater was turned on and kept at 80 - 100° C. The pressure was taken at 10 min intervals until it remained constant. The heater and the motor were turned off, and the bomb was let cool. The contents of the bomb were poured out and fractionated by filtration and layer-separation.

The second experiment was similarly performed with a pressure of 1500 lbs./ sq. in at 120 - 140° C.

## Data for Experiment I.

| No. of run | Amount of oil ml. | Time hr. | Time min. | Max. temp. °C. | Pressure lbs./sq. in. before | Pressure lbs./sq. in. after | Pressure decrease | $H_2$ absorbed % by wt. | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 130 | 1 | 20 | 70 | 300 | 197 | 103 | 0.115 | |
| 2 | 150 | 1 | 10 | 80 | 400 | 247 | 153 | 0.171 | |
| 3 | 200 | 1 | 10 | 80 | 400 | 200 | 200 | 0.138 | left over night |
| 4 | 200 | 1 | 20 | 80 | 450 | 315 | 135 | 0.093 | |
| 5 | 200 | 1 | 10 | 90 | 450 | 321 | 129 | 0.089 | |
| 6 | 200 | 1 | 10 | 80 | 400 | 267 | 133 | 0.092 | |
| 7 | 200 | 1 | 20 | 70 | 400 | 322 | 78 | 0.054 | catalyst used for last time |
| 8 | 200 | 1 | 10 | 90 | 450 | 258 | 192 | 0.132 | |
| 9 | 200 | 1 | 10 | 80 | 400 | 180 | 220 | 0.152 | left over night |
| 10 | 200 | 1 | 30 | 80 | 400 | 295 | 105 | 0.072 | |
| 11 | 200 | 1 | 10 | 80 | 400 | 270 | 130 | 0.090 | |
| 12 | 200 | 1 | 10 | 80 | 480 | 250 | 230 | 0.159 | left over night |
| 13 | 200 | 1 | 20 | 80 | 470 | 318 | 152 | 0.105 | |
| 14 | 200 | 1 | 30 | 90 | 400 | 284 | 116 | 0.080 | catalyst used for last time |
| 15 | 200 | 1 | 10 | 80 | 450 | 250 | 200 | 0.138 | left over night |
| 16 | 200 | 1 | 30 | 80 | 450 | 330 | 120 | 0.083 | |
| 17 | 200 | 1 | 10 | 118 | 420 | 271 | 149 | 0.103 | |
| 18 | 200 | 1 | 10 | 90 | 450 | 100 | 350 | 0.242 | left over night |
| 19 | 200 | 1 | 30 | 70 | 450 | 322 | 128 | 0.088 | |
| 20 | 200 | 1 | 10 | 80 | 400 | 235 | 165 | 0.114 | |
| 21 | 200 | 1 | 10 | 80 | 450 | 250 | 200 | 0.138 | left over night |
| 22 | 200 | 1 | 30 | 90 | 480 | 405 | 75 | 0 052 | catalyst used for last time |
| 23 | 200 | 1 | 10 | 90 | 500 | 379 | 121 | 0.083 | |
| 24 | 200 | 1 | 10 | 80 | 480 | 250 | 230 | 0.159 | left over night |
| 25 | 200 | 1 | 30 | 105 | 500 | 357 | 143 | 0.099 | |
| 26 | 200 | 1 | 10 | 90 | 500 | 352 | 148 | 0.102 | |
| 27 | 200 | 1 | 10 | 105 | 500 | 300 | 200 | 0.138 | left over nigh t |
| 28 | 200 | 1 | 30 | 105 | 500 | 375 | 125 | 0.086 | |
| 29 | 200 | 1 | 10 | 80 | 500 | 300 | 200 | 0.138 | left over night |

## Data for Experiment II.

| No. of run | Amount oil ml. | Time hr. | Max. temp. °C. | Pressure lb s./sq. in before | Pressure lb s./sq. in after | Pressure decrease | $H_2$ absorbed % by wt. | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | 200 | 3 | 120 | 1600 | 970 | 630 | 0.435 | |
| 2 | 200 | 4 | 132 | 1530 | 600 | 930 | 0.642 | |
| 3 | 200 | 4 | 137 | 1500 | 850 | 650 | 0.449 | |
| 4 | 200 | 5 | 140 | 1550 | 550 | 1000 | 0.690 | new catalyst |
| 5 | 200 | 5 | 146 | 1500 | 670 | 830 | 0.573 | |
| 6 | 200 | 5 | 136 | 1500 | 500 | 1000 | 8.690 | new catalyst |
| 7 | 200 | 5 | 142 | 1500 | 560 | 940 | 0.649 | |
| 8 | 200 | 5 | 120 | 1500 | 800 | 700 | 0.483 | |
| 9 | 200 | 5 | 140 | 1500 | 580 | 920 | 0.635 | new catalyst |
| 10 | 200 | 5 | 145 | 1550 | 540 | 1010 | 0.697 | |

In the first experiment, three runs were performed in a day. When the bomb was emptied immediately after it was cool, the decrease in pressure was 134.2 lbs./sq. in. with 0.092% by weight of hydrogen being absorbed, but when it was left over night the decrease in pressure was found to be 225.6 lbs./sq. in. with 0.156% by weight of hydrogen being absorbed. The first run of the day took about 1 hr. 30 min. while the succeeding runs took only 1 hr. 10 min. on account of the heating up of the first run. The same catalyst could be used for about 7 or 9 runs, after which its activity was greatly reduced.

Hydrogenated oil was clear and colourless; it slightly turned yellow on long standing. As compared with the unhydrogenated oil, its keeping quality was improved. It could be used even after a year storage, while the unhydrogenated oil turned viscous within 4 - 5 months.

In the second experiment, where a higher pressure of 1500 lbs./sq.in. at a higher temperature of 120 - 140°C were employed, the run took about 3 - 5 hours. The life of the catalyst was also reduced to about 2 - 3 runs.

| Properties | Unhydrogenated Oil | Hydrogenated Oil from Expt. I. | Hydrogenated Oil from Expt. II | Standard Deisel Oil (A.S.T.M. Standard) |
|---|---|---|---|---|
| Flash point | 48.06 °C. | 91.1°C | 93.0 °C | 43.3—110°C. |
| Pour point | below – 10°C | below – 10°C | below – 10°C. | 6.7°C max. |
| Sediment | nil | nil | nil | 0.10% max. |
| Carbon residue | 0. 02 % | 0.01% | 0.01 % | 0.15% max. |
| Ash | nil | nil | nil | nil |
| Viscosity | 45.6 sec. | 44.2 | 42.5 | 45 sec. max. |
| Sulphur | 0. 06 % | 0.06% | 0.05% | 0.75 % max |
| Distilling temp. 10 % | 255 °C | 257 °C. | 252°C. | — |
| Distilling temp. 10 % | 264.4 °C | 261.1°C. | 260°C. | 315.56-357.22°C |

The hydrogenated oils obtained from this experiment was clear and colourless; it turned slightly yellow on storage.

The hydrogenated oils obtained in both experiments I. and II., campare favourably with the Standard Diesel Oil (A.S.T.M. Standard). The improved properties of the hydrogenated over the unhydrogenated oil are higher flash point, less carbon residue, and lowered viscosity. The most important point is that the hydrogenated oil shows a better keeping property. This stickness would undoubtedly cause troubles in running the engine. The oil from the second experiment absorbed about 0. 529% $H_2$ by weight, i.e. about 4.6 times that of the first experiment, consequently it is expected that its keeping quality will be much better. Theoretically, gurjunene would absorb 0. 98% $H_2$ as calculated from its formula, but in these experiments only 0. 15% and 0. 53% $H_2$ were absorbed Thus it is quite probable that the hydrogenation was still incomplete.

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# PRELIMINARY NOTES ON THE GEOLOGY OF THAILAND

**Smak Buravas, B.Sc. (Hons.), A.R.S.M.**

The history of geological exploration in Thailand dated back to the early nineteenth century when J. Crawford made a geographical expedition from Bengal to Thailand and Cochin-China. In 1824 his works appeared in the Transactions of the Geological Society, London.

Seventy years later there was published in the Mineralogical Magazine an artical on "The Ruby and Sapphire Deposits of Muang Klung, Siam." by Professor Henry Louis. In the article, a complete analysis of the gem-bearing basalt was given and this marked the first attempt of serious geological study in Thailand. About the same time, Sir H. Warington Smyth, F.R.S., wrote several articles on "The Stones of Upper Siam." in the British Geographic Society Magazine.

In 1899 a real geological survey was conducted by the Cambridge Exploration Party at Kow Din Soh (hill of slate pencil) in the province of Patalung, Southern Thailand. The party described the first and probably the largest collection of Carboniferous fossils in this country and their work had been supplemented by that of F.R. Cowper Reed in the Geological Magazine in 1920, in which the fossils were identified and described. Then in 1902, appeared a book on "Surveying and Exploring in Siam" written by James McCarthy, F.R.G.S., Director of the Survey Department of Thailand. Though this was rather on geography of Upper Thailand than on geology, it contained a lot of informations on Thai rocks.

A rough, yet systematic, description of Thai geology was given by H. Bertil Hogbom in the "Bulletin of the Geological Institute of the University of Uppsala" in 1913. A more careful work on behalf of the Royal Railway Department was conducted by Wallace Lee, an American oil geologist and Phra Udom Pityapoompijarn, then the

Director of the Geological Section in the Department of Land and Mines. W. Lee attempted to give the general stratigraphy of northern, southern, and eastern parts of the country. His reports were published by the Railway Department in 1923. In 1928–1929 Dr. Wilhelm Credner, a German geographer made sevaral visits to various parts of Thailand for the purpose of collecting facts for his famous book "Siam". His other work on geology appeared in the "Journal of Siam Society, Natural History Bulletin, Vol. VII".

Later, in an attempt to find out probable occurrences of oil deposits within Thai territory, The Government of Thailand, asked two Swiss geologists, Dr. Arnold Heim and Dr. H. Hirschi to examine the deposits of the tar-sand at Farng and oil-shale at Mare-Sord. The two geologists were joined by Phra Udom and Khoon Pien Lohapitya, officials of the Mines Department. They made several cross-cuts along geological outcrops in the North and these Swiss geologists wrote two manuscripts on geology about the tracts from Tark to Mare-Sord and from Farng to Chieng Rai. Since then several other foreign geologists had visited Thailand, among those were Y. Naito, a Japanese geologist; K.A.H Buss, a Swedish geophysicist; Prof. Shimitsu, Prof. Kawaji, Captain Radford of the British Army and an American geologist, Prof. Khokimo.

Another work of a similar nature appeared in the "Geologic Reconnaissance of the Mineral Deposits of Thailand", issued as a Geological Survey Bulletin, No. 984, by the Technical Co-operation Administration of the U.S. State Department. This was compiled by the U. S. Geological Survey in co-operation with Thai Department of Mines.

On the Thai side Phra Udom Pityapoompijarn and Khoon Pien Lohapitya had done a lot of pioneering work. Some further investigations have been made after Vicha Sedhabutra, Smarn Buravas, C. Charun Chavanapet, Nitipat Chalichandra and several geolgy-graduates from Chulalongkorn University joined the staff at the Department

of Mines. One also could not neglect some contributions made by two other geologists outside the Government Service-C. Kanchanakom and S. Pisolyabatra.

Smak Buravas was appointed the Mining Inspector to the Department of Mines in 1934. He has been travelling widely but has been very modest in stating that he has never had an opportunity in making a single systematic geological exploration. However experiences obtained from visiting mines and prospects throughout the country enable him to present a general view on Thai stratigraphy. After leaving the Department of Mines he had done a lot of prospecting works for the Thai Cement Co., the Thai Mineral and Rubber Co., and the Naval Signals Department, the Royal Thai Navy. On these occasions he had further opportunity in studying local geology and ore-deposits in various localities.

One may consider his attempt at a systematic description of Thai Geology incomplete and possibly controversial but he has to be congratulated in presenting this valuable account providing a view on Thai stratigraphy which not only would interest geology students but also be a great help in future geological exploration and in Mineral prospecting in Thailand.

The author also wishes to thank through the Thai Science Bulletin, officials of the Thai Department of Mines for valuable geological informations, Dr. Pendleton of the Department of Agriculture for his advice on the origin and types of Thai soils, and the mine owners and superintendents in various provinces for their kind assistance during his prospecting work.

*Editors.*

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## Physical Features & Morphology.

Thailand lies between the parallels of 5° and 21° North latitude, and between the meridians of 97° and 106° East longitude. Its greatest length is 1650 kilometers and its greatest breadth 800 kilometers.

The country is bounded on the west by Burma, on the east by Indo-China and on the south by Malaya.

Geomorphologically, it may be divided into seven regions as follows:

(1) The northern region: The structure of northern Thailand is better understood by reference to the three great rivers, the Salweens, the Mekong and the Yangtze Kiang. These three great rivers of south-eastern Asia rise in the Kwenlun of Tibet and flow parallel to one another down south for a distance of more than 400 kilometers. For most of the track their beds are not more than 30 kilometers apart, being separated by precipitous ridges. At Latitude 27° the Yangtze parts company from the other two and turns abruptly to the east to meander a further 2500 kilometers through China before reaching the sea. The Mekong takes a sharp turn to the east in the Latitude of 20° N. and flows along Indo - China - Thailand frontier eastwardly as far as Luang Prabang. It then turns southward to Chieng Kan, takes an eastward route again at that locality and turns straight south at Nakorn Panom to reach the sea at Saigon at Latitude 10° North. The Salween, on the contrary, continues to flow south with a westward drift until it reaches the Indian ocean at Moulmein at the Latitude of 16°.

The main ridge between Mekong and Salween at the point where they part company, becomes part of the northern frontier of Thailand. This range of mountains is known as the Dan Lao. It breaks into a number of parallel ridges with a general NNE-SSW trend. This, according to W. Lee, conforms with the strike of geological folding in the region. The western ridge known as the Thanon Thong Chai has

a NNW - SSW trend. It lies along the north - western Burma - Thailand frontier and is taken to be the limit of northern region. It has been supposed by some geographers that this Tanon Tong Chai range continues south to from the backbone of Thai peninsular. This may be correct if all the other ranges parallel to this one, which begins in the north, have the same name. In the study of geomorphology, regions have been divided according to their characteristic morphology. Therefore, this Tanon Thong Chai range should be fixed to end somewhere east of Mare Sord. East of this ridge is Khun Tarn range which has a granite core. The Khun Tarn range is not strictly along a NNE - SSW direction but seems to be bent, due to compound earth folding. The Pi Pan Nam mountains are placed next to Khun Tarn range. They also show NE - SW structure with modifications from the effect of NW bending. The eastern termination of the northern region seems to be along a N-S line which passes through Nan. East of this line is a continuation of the Korat plateau.

Thus the northern region comprises seven provinces namely Mare Hong Sorn, Chieng Mai, Chieng Rai, Lampang, Prae and Nan.

Between the mountain ranges are the valley of the four tributaries of the Chao Phya river namely the Me Ping rising in the Dan Lao range, the Me Wang, the Me Yom and the Me Nan.

The areas containing these rivers are mountainous but there are level stretches here and there along the larger streams, e.g. at Chieng Mai, Lampang, Prae and Nan. These stretches are composed of alluvial deposits resting on basin deposits of Tertiary age. They are therefore suitable for rice growing. As a result, the areas have been thickly populated and are the seats of the principal towns of the provinces. Before entering the plain of the Chao Phya River, These rivers pass through precipitous banks and rapids along most of their lengths. North of Pi Pan Nam ridges are wide swampy plains drained by the Menam Ing and Menam Kok (Menam = mother of water = river). These flow into the Mekong.

The northern region joins the central plain at about Latitude 17° 40' north. The mountainous region with narrow valleys gives place to a wide alluvial plain with only occasional hills rising up from flat bases.

The northern region contains the highest mountains of the country. The plain of Chiengmai is 300 meters and Chiengrai 378 meters above sea level. The average height of the peaks is 1600 meters, Doi Angka or Intanon, the highest mountain, rises to a height of 2576 meters. The celebrated Doi Sutep which overlooks Chiengmai from the west is 1676 meters high, Doi Pa Cho 2012 meters and the highest limestone mountain Doi Chieng Dao, 2185 meters.

(II) The western region: This region begins at Rahang. It occupies an area west of the Great Central Plain and extends as far south as Prachuab Kirikhan. Really, it is a continuation of the southern region. It consists of parallel ridges of mountains along NNW-SSE to NW-SE trends. Among these ridges are the conspicuous limestone hills and mountains which run through Kanchanaburi, Rajaburi and Petchaburi. Flanking the limestones on both sides are Paleozoic sandstone and shale mountains. On the west side next to this latter formation, the mountains are of granites. At Rajaburi, Petchaburi, Ban Cha-am, Sam Roi Yot and Prachuab Kirikhan there are limestone pinnacles rising out of the rice plains. They are bounded by vertical cliffs, which seem to rise abruptly from the plains. Probably they are the remnants of limestone islands in the late Pleistocene sea. North of Rajaburi and west of Kanchanaburi the flat plain gives way to a mountain landscape. This region is drained by Quare Yai and Quare Noi rivers which join at Kanchanaburi to flow to the sea through the Great Central Plain. North of Kanchanaburi is, perhaps, the most mountainous part of the country.

(III) The Korat plateau: Korat plateau is one of the most conspicuous landscape of Thailand. It is bounded on the south by a range of hills called the Phanom Dong Rek, on the east and north by

Mekong river and on the west by Pasak river. It also occupies the region east of Nan.

It is a saucer - shaped plateau tilted to the S.E. On the north and east it is guarded from the Mekong by a line of sandstone hills varying in heights up to 600 meters. It is drained by the river system of Nam Mun in the central part and by the tributaries of Mekong in the north.

The western and northern sides of the plateau are from 130 to 200 meters above sea level. At Muang Ubon, which is situated at the mouth of Menam Mun, the level is 50 meters in height.

The rim of the plateau is mountainous. Certain parts of this is composed of folded mountains of Permo - Carboniferous limestone-shale formation. The eastern railway line passes through this region between Saraburi and Chantuk. The other rock formation consists hogback sandstone mountains, usually having comparatively flat tops. On some of them; there are wide plains which were thought by Credner to represent the original surface of tne country. The Korat plateau is, then, essentially a region formed mainly by erosion. The sandstone strata are only slightly tilted. These flat - topped mountains may be seen at Prajeenburi. The celebrated Pu Kadung with its wide healthy plain on top is also within this region. Generally, this mountainous rim of the Korat plateau meets the Great Central Plain at high angles, while it seems to slope imperceptibly down to the plateau. At Prajeenburi this queer structure is clearly seen and suggests the presence of a great fault which bounds the southern and southwestern part of the plateau from the central plain. The structure of rocks in the plateau itself is gently undulating so that by weathering a comparatively level plain was the result. On the plain there are few true alluvial soil deposits. There are only patches of swampy ground on which rice is cultivated,

The mountains north of Prajeenburi and west of Nakorn Nayok are from 800 to 1300 meters in height. The highest peak is Kao Lam which attains a height of 1328 meters. The Dong Rek scarp

which runs from Prajeenburi eastwardly as far as Me Kong is from 400 to 700 meters high. Some sandstone mountains northwest of Loei vary in heights from 1000 to 2000 meters. East of Nan the sandstone mountains formed mainly by erosion are of similar height. The Nam Mum which drains the central part of the plateau has its origin in the Dong Phaya Yen mountains. Its principal tributary, the Nam Chi, rises in a region north of Nam Mun. The Nam Pau carries off the surplus water from two great freshwater lakes lying to the north of the plateau and empties itself into the Nam Chai. The plateau is flooded during rainy seasons. The numerous cart tracks are then impassable. In dry season water is quite scarce.

A strip of land north of the plateau varies in width from 50 to 100 kilometers. It is drained into the Mekong. Nong Laharn, the largest freshwater lake in Thailand, is in this region. It had an area of about 170 square kilometers and is connected to the Mekong by a stream called Nam Kam. There is only one important river within the area, called Menam Songkram. This has a reverse current for many kilometers up stream if the Mekong is flooding.

Mekong itself is one of the world's greatest and largest rivers. It runs through precipitous cliffs, impassable rapids and high alluvial banks. Its breadth varies from 700 to 1300 meters. The general belief that Mekong flows along a fault line is unfounded as this cannot be proved geologically. No doubt the track of the river is controlled by the earth movement which had caused the plateau to be formed.

(IV) The south-eastern region: The region south of Dong Rek scarp had been interpreted by Hogbom as being formed by the downward slip of sandstone shale strata, during E-W bending, which gave rise to the E-W Dong Rek ridge. It is mostly a laterite covered country with gently undulating surface. There are few scattered hills, all of sandstone and shales. Being bounded by high ground in the north which is a good leaching ground from which iron solutions had come, the area is highly favourable to laterite development.

The other characteristic feature is the presence of limestone inliers which rise abruptly out of the gently folded sandstone-shale strata of Triassic Age. These limestone formations are of Permo-Carboniferous Age. They are also highly fossiliferous.

The highest peaks in the region are of limestone and rarely exceed 400 meters in height.

The region is drained by several tributaries of Menam Bang Pakong. These streams have their origins in the Dong Rek scarps and Chandaburi mountains. One great tributary, the Menam Nakorn Nayok, rises in the Dong Phya Yen mountains.

Compared with the flat country immediately north of it, the southern part of the south-eastern region is hilly. It is bounded on the east by a range of hills called Kao Ban Tat. This range of hills is a godsend for it precipitates so much rain from the southwest monsoon that the region may be considered one of the wettest and most fertile part of Thailand. It is also a region of red soils and laterites. The structure is complex but there is persistence of NW–SE structure coupled with E-W folding effect. There are many intrusions of basalts and granites which somewhat tend to destroy structures and textures of sedimentary rocks.

The principal peaks in Chandraburi mountains are of granites. They are Kao Keo, 800 meters high, Kao Soi Dao, 1640 meters and Kao Sabab, 933 meters. Kao Keo or Kao Bang Pla Soi is the only mountain visible from Bangkok.

The region is also bounded by a coast which is much indented and closely fringed with rocky and jungle-clad islands. The island Koh Si Chang lies near the northeast corner of the Gulf of Thailand and forms a good natural shelter for large steamers which cannot cross the bar of the Chao Phya River. Koh Charng is the largest island on the east coast. It has an area of 180 square kilometers. It is 30 km.

long and 10 km. wide. The highest peak on the island reaches 644 meters. Other islands next in size are Koh Kood and Koh Kram.

The area is drained by numerous streams, all flowing in a southerly direction, the chiefs of which are Menam Chandaburi, Menam Wen and Menam Trad.

(V) The high ground immediately west of Korat plateau: This area lies immediately west of Korat plateau. It is an intermediate zone between Korat plateau and the Great Central Plain. The area comprises Petchaboon, Pichitr, Nakorn Swan, Lopburi and Saraburi. At Prabat, the region is bounded from Chao Phya plain by a limestone massif which meets the plain nearly at right angle. The region is generally much higher than the plain of the Chao Phya river. At Kok Sum Rong there is a basalt plateau bounded on the west by a Triassic sandstone formation. This plateau is only 50 - 80 meters above sea level. Limestone is predominant in this region. The structure is faithfully NNW - SSW to NW - SE so that the limestone ridges have been arranged along this general trend. The limestone formation seems to be a continuation of that found between Saraburi and Chuntuk. The limestone hills also run into the Great Central Plain at Ban Mi, Hua Wai, etc. The highest peak in this region is Kao Nang Pra Chan (800 meters), in Lopburi. This is composed of andesite porphyry and microdiorite. The limestone hills rarely exceed 300 meters in height.

The Pa Sak river, which runs through it, rises in the mountain of Petchaboon. It drains this area and the mountainous rim of Korat Plateau. Most of its journey is through rapids, and rocky bottoms. The river reaches the Central Plain at Saraburi, where it has been utilized to irrigate a large part of the lower plain between Menam Chao Phya and Menam Bangpakong.

It may be noted also that it is the driest region in Thailand. The dryness is reflected by the development of much calcium carbonate

in the subsoil. The presence of limestone, of course, favours the development of this substance, but the material has been found to be developed also in basalt, rhyolite and porphyry soils

(VI) The southern region: This area begins at Kao Luang (1247 meters) in Prachuab Kirikhan. The mountains are mainly of granites and may be seen near the Southern Railwayline at Huey Yang. North of this peak is one of the lowest passes across the Burma - Siam frontier, the height of which is only 237 meters; it is known as the Galinga Pass or Chong Singkorn. This ridge passes into Lower Burma to reach the sea at Victoria Point. It has a granite core. Another ridge parallel to this begins north - west of Chumporn. It is kept apart from the former by the Menam Kra. This range passes through Chumporn, Ranong, Phanga and Puket, having like wise a granite core.

The main ridge of southern region starts afresh at Koh Tao (granite). It then passes through Nakorn Sritamaraj, Patalung, Trang, Singora and Setul and is known as Nakorn range. This contains the highest peak of the region, Kao Luang (note: any highest peak is called Kao Luang, meaning "Great Mountain"), which rises 1786 meters above sea level. Another high peak, Kao Men is 1309 meters in height. They are all of granites and these rocks also constitute the core of the Nakorn range. The northern part of this range comprises two other granite islands known as Koh Phngan and Koh Smui. Near Na Sarn the range seems to branch off somewhere in Katoon to approach the Southern Railway line. In that district some mountains are of granites and are tin - bearing.

Generally speaking, all high peaks seen in southern Thailand are composed of granites.

Between the Tenasserim and Nakorn ranges is an undulating country with hills rarely exceeding 300 meters in heights. The most conspicuous of these are of limestones. There is only one massive hill in this region, Kao Panom Benja, which is 1404 meters high.

It is probably composed partly of hornblende - granite. A flat plain is present east of Nakorn range. This extends from Sichol along the coast to as far as Singora. Rising abruptly out of the plain are many limestone peaks, the most spectacular being in Patalung. The plain is drained by many small rivers. Some of these feed an inland sea called Tale Sarp Songkla (Singora lake) which is studded with limestone and sandstone islands.

There are many other high range in Yala, Pattani and Naradhivas, all with granite cores. The range which borders the southern Malaya - Thailand boundary is known as the Kala Kiri. North of this range the area shows the effect of E - W bending.

The general trend of mountain ranges in the southern region is a compound effect of NNW - SSE and NNE - SSW earth foldings. Thus, the Nakorn range is curved. The Tenasserim has however a NNE - SSW trend.

Streams originating in the mountains mostly run out of E - W cracks in rocks, The largest river is the Menam Ban Don which receives its water from two great tributaries, the Menam Tapi and the Menam Kirirat. This river system drains a wide area between Puket and Nakorn range.

Islands are common on the west coast of the Thailand peninsular. Among these may be mentioned Koh Pratong, Koh Kor Kao, Koh Puket, Koh Lanta and Koh Tarutao. Koh Puket is the largest and the most precious. It consists of many outcrops of granites and hence is rich in tin ore. The sandy island, situated at the mouth of Takuapa river, known as Koh Pra Tong is also tin - bearing.

Islands on the east coast are few in number. Two granites islands Koh Phngan an Koh Samui are the best examples. They are both tin and tungsten bearing.

(VII) The Great Central Plain: It is the Great Central Plain with rice fields extending as far as the horizon that tourists get

impression of this country. This great plain is over 300 kilometers in length and varies in breath from 50 to 150 kilometers. The level of the ground is generally low. At Latitude 18° the banks of the Me Yom are 44 meters above sea level, at Paknampoh the banks of Chao Phya river stands only 25 meters about the sea. The deltar of the river system may be said to begin at Chainart. There are many evidences which tend to prove that at the close of the Pleistocene era the sea was as far as this point. The ground at Chainart is 18 meters above the mean level, at Ayudhya 4 meters and at a Bangkok only 1.80 meters. The plain is therefore extremely flat and liable to become inundated at the end of the rainy season.

It is not far wrong to say that to the layman in Bangkok this great plain represents the whole of Thailand. This is the general impression of foreign visitors and of Bangkok people. The region is the most thickly populated and inspite of its rather small size, comprises as many as twenty one provinces.

There are some low hills on the plain in the province of Nakorn Swan, Sukhotai and Pitsanulok. These seems to be the continuation of Lopburi ranges. North of Nakorn Swan, there seems to be another flat ground bounded by hills at Paknampoh, which is south of it, and by high ground with occasional hills in Pichitra, Pitsanuloke, Utradist, Sukhotai and Tark. These hills of Paknampoh serve as a bar to resist the enormous movement of river water during the flood time; and as a result, the plain north of Paknampoh is very badly flooded.

The Great Central Plain is drained mainly by the Chao Phya river, the most important river of the country. This great river begins at Paknampoh where two tributaries called Kware Kampang and Kware Yai come to join up into a river. Kware Kampang branches off northwardly to form Mare Ping and Mare Wang, While Kware Yai forms Mare Yom and Mare Nan. The Chao Phya river itself bifurcates near the old Chainard, to form a

delta 90 kilometers long. The principal branch is known as Menam Tajeen. This river is remarkably straight. The eastern branch breaks up into Menam Noi, Menam Yai and Menam Lopburi. At Ayudhya the Chao Phya river is joined by Menam Pasak.

The region around Bangkok if full of artificial canals. These, at one time, had been the principal means of communication.

Several other rivers pass through the Central Plain. They are Menam Meklong, Menam Petchaburi, Menam Bang Pa Kong, Menam Nakorn Nayok and Menam Utaitani.

Great quantities of silt are brought down and deposited on the bar at the mouth of the river every year. It has been calculated that Thailand gains 4 - 5 annual meters of land seawardly. By perennial inundation the level of the plain is also made higher every year and where the fisherman now casts his net, the farmer will be sowing his seeds a thousand years afterwards.

## Climate

Thailand has a monsoon climate. The year may be divided into three distinct seasons. The wet season begins about the end of April and lasts to the middle of November. The climate is under the influence of southwest monsoon. It is hot and damp with occasional rains and thunder storms. The winter or "Cold" season is under the influence of northeast monsoon. It begins at the end of the wet season and lasts to the middle of February. In Bangkok the temperature may come down as low as 10°C., but at Nan the climate is much colder, the freezing point is very often reached on the mountains. The air is also dry. The Thai winter has a pleasant climate with very little rain. The summer or hot season extends from the middle of February to the end of April.

In the south, on the west coast of the peninsular and west of the mountain ranges (e.g, in Ranong, Takuapa, Phanga, Ruket), the wet season exists during the same months as in northern Thailand but on the east coast of the peninsular and east of the mountain ranges, the wet season is later, begining in August and ending in January to February. There is no distinct cold season in this region due to its more southern latitude and there is no real summer because of the southwest monsoon. Generally the southern climate is cool and damp all the year round and is pleasant to life.

The average rainfall for the whole country is 1600 mm. or 63 inches. The greatest rainfall occurs along the coastal region between Puket and Ranong where the yearly average is as much as 3300 mm. (130 inches). It is also very high in Chandaburi and Trad, The region of least rainfall is between Lopburi and Korat where the average is only 880 mm. On the Central Plain the rainfall is 1052 mm. Hence the farmers have to depend much on the inundation of the rivers for the cultivation of their crops. The period of inundation begins in October and ends up in November.

## Vegetation

In Thailand various types of vegetation have been found to depend on climate and topography.

On the Korat Plateau, and in the south-eastern and Lopburi-Saraburi regions there appears what is known as the "dry forest" or in Thai "Pa Dang" (red forest). This grows on poor stony soils or laterites, under medium or scanty rainfall. The trees found are mostly of the hard-wood type and consist principally of *Shorea obtusa* and *Pentacme siamensis*. Between the trees lalang grasses may grow in abundance.

On the hills and in the dry region bamboo of the species *Thyrostachys siamensis*, Gamble is mostly seen. This bamboo is common in Rajburi, Lopburi and the upper part of Sraburi being absent altogether in Thailand Peninsular and on damper soils.

On top of the mountains in all parts of the country there are evergreen forests. The number of species of trees in this type of forests is very great and has been placed as 200 or 300 per square mile. Most of the giants belong to the family *Dipteracarpaceae* This type of forest covers most of the plains and mountains in the western, southern and lower part of south-eastern regions.

Mangroves grow in abundance on mud flats at the mouths of mud-laden rivers. The mouths of the rivers of the Great Central Plain and of the west coast of the Thailand peninsular are particularly favourable to the accumulation of mud flats and hence there are extensive mangrove areas.

Mixed deciduous forest is common in the northern region. Teak is the principal product of the forest.

On the high peaks of this region, trees of the temperate climate could grow. There have been found several species of roses, rhododendrons and oil-bearing pine trees.

The *Banbusa spinosa*, Roxb. grows luxuriantly on the banks of streams and rivers. They seem to confine themselves to water-bearing zones and regions of medium precipitation only. Another species without thorns and with softer wood has been found to grow luxuriantly on the slopes of hills and mountains in the south.

Animals in the forests are not so numerous in species. They are tigers, barking deers, common deers, black leopards, wild oxen, wild buffalo, rhinoceros, elephants, pythons, cobras, crocodiles, vipers and game birds. They are, however, rarely seen.

## The Pre-Cambrian.

One of the most difficult task in geological exploration in Thailand is the interpretation of local stratigraphy. Most part of this country is under heavy monsoon and the rocks are all weathered down to great depths. The overlying soils are also thick. The writer had tried several times to climb to mountain tops in order

to look for real outcrops but he only found loose stones and soils. Also, predominating weathering products are not usually of the underlying rocks but had been carried far from the mountains by running water which flows past all types of rocks in the lower levels. In the south, for example, granite rocks seem to be the core of all high ranges and they are exposed on the mountain tops. Accordingly, weathering products of granites have covered vast stretches of land in southern Thailand. Only at the base of hills do soils belonging to the underlying rocks exist, the plain of the valleys being filled with granitic soils mostly.

As a result of weathering, silicified sandstones had been altered into porous sandstones; shales and sandy shales crumpled down into clays and only traces of bedding planes are seen; sandstones were reduced into ordinary sands; wellbedded limestones were eaten through by percolating water, calcite filling all the crevices present; they therefore appear as rugged outcrops with pinnacles and steep cliffs. Granites were kaolinised down to depth of over one hundred feet. Pegmatites, aplites and granite prophyries were also weathered in situ. All these weathered rocks serve to make geological exploration very difficult indeed.

Lateritisation, interpreted by Thai geologists as a cementation of residual soils by hydroxides of iron, had turned loose soil into a hard pan. In the region of laterites, therefore, outcrops of rocks cannot be seen or found by simple pitting. The laterites themselves do not show distinctive constituents which would show the nature as the rocks underlying them as they may be formed from all types of rocks, that is from limestones and sandstones as well as from andesites and basalts.

Vegetation is also thick and thorny in the monsoon forests. The forests in the south are therefore almost impenetrable. Heavy

rainfalls are also drawbacks. In the jungles roam the bears, the tigers and the pythons, and the insects are not less harmful than the wild animals just mentioned, There are also land and water leeches which bite and suck bloods from man. Malaria is, of course, a deadly disease which awaits uncareful trespassers. Prospecting life in this country is therefore not very inviting.

Dacoits are very few and they would not touch prospectors who do not report them to the police. Prospectors are helpless against dacoits as it is they who shoot first. The writer has found it safer not to take any pistol into the jungle as dacoits may shoot first if they see some one with weapon. Wild animals are very rare and weapon is quite unnecessary as an equipment for jungle travelling.

Also in this country there are always some villages even amidst the densest jungles. There are cart tracks and foot-paths ramified in all directions throughout the country and one almost can get to any point on the map. It is advisable to follow the cart tracks or the foot-paths and not to try to make shortcuts as they take more time and give more trouble.

Geological structures present also other drawbacks. Usually contacts of geological bodies are not found, as wide valleys cover and separate them. Foldings are also intense and give rise to anticlinoriums and synclinoriums. Sometimes there are overthrust folds and numerous faults, There are also several igneous intrusions which tend to destroy structures and conceal the original nature of the rocks through metamorphism. Fossils are quite rare except in the permo-carboniferous and tertiary formations.

Nevertheless, as Thailand has a long sea coast, outcrops of rocks along the sea side give quite a clear idea of local geology. They show finest bedding planes and laminations and the structures may be studied with confidence. Numerous streams also serve to expose the

bed rocks and their structures. In the dry region or dry forest, outcrops of rocks are easily seen if the region contains no thick bed of laterite. There are innumerable wells excavated by the local inhabitant for water supplies. These may be examined, as the materials dug up always include pieces of the bed rocks.

To form an idea on Thai stratigraphy, wide travel is necessary and various formations of rocks are to be remembered and specimens of rocks taken. Luck is the clue to discoveries of "key - geology", which shows one decidedly and plainly various beds of rocks in one geological formation and relative age between two or more formations. Fossil localities also have been found through cheer luck, but it is a fact that one who travels most has the most chance to be lucky.

Stone quarries are not numerous in Thailand and they do not help much in throwing lights on local geology. They are mostly in massive limestones or igneous rocks. Mines, especially gravel - pump mines, give good exposures of bed rocks. Moles, crabs, ants also help to bring pieces of rocks from underground to the surface,

Fallen trees are also helpful as their roots always show stones attached to them.

Being altogether blank at first with regards to Thai geology, the writer had to start with horizon of known age first, and this is the Permo - Carboniferous limestones. He next studied rocks above and below the limestones and then completed the whole stratigraphy for Thailand. W. Lee's succesions of rocks in the north and the south are also very helpful and very accurate, although they do not contain sufficient informations. At present although all formations of rocks have been recognized there are some beds which are difficult to place in any systems. There are also uncertainties in placing one formation above or below the other and there must be more discoveries to settle the problems.

There are many groups of metamorphic rocks which seem to

flank both sides of the plain of the Chao Phya river. They are also of wide occurences throughout Thailand, except on the Korat plateau. In the south, they have been found in Yala, Nakorn Sritamaraj and Sichol, and are mostly of schists, quartzites and granite gneisses. Hua Hin has gneisses and Rajburi, quartzites and schists. Metamophic limestones, quartzites and gneisses seem to be the crystalline floor of south-eastern Thailand on which were deposited the Permo-Carboniferous and Triassic rocks. The plain of Chieng Mai is also on top of a crystalline floor and there is a belt of metamorphic rocks runing across the Chao Phya plain from Chainad to Pak Nam Poh. These will be described more fully when we come to more detailed descriptions of the metamorphic groups.

*a. Sri-Raja Series.*

The Sri-Raja formation is exposed as a range of hills four kilometers broad and is aligned along a NNE-SSW direction. Individual hills rarely rise above 1000 feet altitude. The formation extends from Kao Din in Cholburi to Lam Chabang, being well exposed along the sea side from Sri-Raja to Lam Chabang and may be closely studied. It is not found above or below any other formation, as wide plains cover all the contacts and granitic rocks have been found to intrude it at innumerable points.

Most part of the formation appears as quartzite which is so highly metamorphic that it nearly appears as chalcedony or vein quartz; but the bedding plane is still perceptible. Other rocks belonging to this formation are crystalline limestones and schists. These are not over 75 meters in thickness, they therefore crop out in certain places only. Pre-Cambrian granites metamorphosed and intruded these rocks all along the coast, while inland they were squeezed by a large batholith of Cretaceous granites. Along the coast archaic igneous activity may be seen at many points; and by the appearances of wide outcrops of Pre-Cambrian granites at Kao Pra Bart, Ang Hin Lam Tan and on some islands east of Koh Si Chang, it is inferred that

the sea between Sri Raja and Koh Si Chang has its floor of Pre-Cambrian granites, such that the coast of Sri Raja and the east coast of Koh Si Chang represent roughly the lines of contacts between these granites and older rocks.

The well-metamorphosed quartzites with horizons of quartz schists are not to be compared with younger quartzites found near igneous contacts. In various parts of the country Cretaceous granite rocks have been found in contact with shales, sandstones and limestones, but these rocks had been completely altered into wholly crystalline products only for a few metres away from the contacts. It is still traceable where rocks had been metamorphosed; that is, the metamorphic rocks of newer formations may be traced to a point where their original nature may be seen. At Suttaheap, fifty kilometres south of Sri-Raja, various non-metamorphic beds of shales, sandstones and limestones had been intruded by Cretaceous granites but they are only slightly metamorphosed.

As for the Sri-Raja formation, extensive search had failed to reveal the original rocks from which they had been derived They are wholly crystalline, the limestones, quartzites and schists. Also they are much folded and there are contortions within the textures, so that they may be called contorted quartz schists, contorted schists and contorted crystalline limestones. Within the general structure which is north north east to south south west, one can yet see minor foldings which are intense and had squeezed the rocks into anticlinoriums and synclinoriums. Repetition of folding and recumbent folding had exposed the under beds of crystalline limestones and schists near to the sea level; but on top of the hills, quartzites only are seen. Being wholly metamorphic the rocks do not show any traces of fossils but they must have survived many ages of fofding so that one can see remnants of those ancient forces all combined into complicated warpings of the rocks.

The thickness of Sri-Raja formation cannot be well over 1000

feet but no definite thickness could be given as the rocks are highly folded. The successions from bottom upwards would be thus:

(1) The lowest stratum is of massive quartzite which does not show any bedding plane. This is exposed at sea level in the Bay of Kasue near Sri-Raja.

(2) The next bed is a crystalline muscovite schist but is not contorted. This crops out at Koh Loy ane Ao Kasue.

(3) On top of the schist are well - bedded quartzites alternating with quartz schists. This bed may be seen at Ban Fung Dang, Ao Kasue and at Kao Din, five kilometres east of Ao Kasue. The quartz schist contains over 93 percent silica and 4 percent alumina. It may be claved into one centimetre plates but the plates are not truly flat and they may break crosswise to the schistosity plane. From Ao Kasue to Lam Chabang this stratum is highly faulted along NW - SE and E - W directions, with fault breccias filling the whole of the fault planes. The faults are however of minor extent only.

(4) The stratum of crystalline limestones has its base of sandy shale and fine limy siliceous shales or "Silex". The middle portion is of wholly crystalline blue saccharoidal limestones not much different from Si Chang crystalline limestones. The top parts it again of fine limy siliceous shale, the next rock being shaly limestone of similar nature to the middle portion, only more shaly. The stratum has a thickness of 20 - 30 metres. This bed crops out near sea level and may be seen at Bang Pra and a Sri - Raja hospital. This horizon never crops up on hills east of the coastline.

(5) This is the uppermost stratum. It is of highly metamorphosed quartzite, such that it usually appears very much like vein-quartz. Sometimes it is splintery and is charlcedony - like. The silica content is well over ninety five percent and the texture is just right for being used as a silica rock in making silica bricks.

Sri - Raja series is never found anywhere else; but there are similar beds cropping out at Rajburi and Petchburi. At the two places schists overlain by quartzites at quartz schists may be seen from Kao Wang to Kao Gan Jan in Rajburi province. W. Lee and the writer observed a bed of contorted marble at the base of Doi Sutep, Chieng Mai. This is interbedded with schists and quartzites. The marble had been metamorphosed by the intruding gneissic granites into a wollastonite - garnet rock not unlike Sri - Raja limestones at Bang Pra.

The Sri Raja series had been intruded by both Late - Cretaceous and Pre - Cambrian gneissic granites, to which reference will be made later.

*b. Si Chang Limestones.*

Limstones comprising the Si Chang series are best exposed at Koh Si Chang, an island fifteen kilometres west of Sri - Raja. There the rocks may be closely studied and the name "Si Chang limestones" has been given to them on account of the best opportunity afforded in studying various details of the rocks. Lithologically the Si Chang limestones consist principally of soft, dirty, well–laminated, metamorphic, wholly crystalline, bluish to dark grey limestones. The mass is built up of alternate layers of pure and argillaceous limestones and iron pyrite. Occasionally there are flat nodules of white milky silica scattered through the rocks. These seem to be syngenetic with the limestones and may be metamorphosed sponge remains or inorganic concretions. However extensive search did not reveal even the slightest traces of fossils. The rocks seem to be composed only of crystalline minerals, and the crystalline nature appears as saccharoidal texture of the rocks. Si Chang limestones are all of calcareous nature but there are special bands of dolomite of pinkish and greyish colour interbedded with it. These has been found at the northern-most end of the island. The existence of the dolomite, so near to Bangkok and so accessible, is indeed a very welcome thing as Thailand is fast deve-

loping her iron and ceramic industry. It is to be noted that the main mass of Si Chang limestons has been built up of soft calcium carbonate, while certain portions of the formation, not exceeding five-metre wide, carry hard dolomite.

At Koh Si Chang the rocks show well developed bedding plane with general strikes from N 30° E to N 45° E and have a persistent westerly dip at 25 to 50 degrees to the horizontal. On close study, even the laminations themselves may be seen to be affected by the foldings and the rocks decidedly appear as contorted crystalline limestones. As is the usual case with Sri-Raja series, there are other directions of foldings such as NNW to NW.

Koh Si Chang is composed wholly of Si Chang limestones. At Koh Karm Yai the same rocks may been seen dipping to the west, with intrusions of gneissic granites.

Si Chang limestones had been first studied at Kao Yai and Koa Pu Rang in Kanchana buri and the characteristic difference between these and the Permo-Carboniferous dolomitic limestones on the other side of the river had been noted. The principal rocks west of Kanchana buri town are brecciated massive dolomitic limestones which rarely show bedding planes. These are the same as the Plateau limestones of Burma described by Schibber as belonging to the Devonian system. The formation is finely crystalline and fossiliferous. It is only metamorphic in parts, appearing occasionally as fine-grained marbles but never coarsely crystalline like Si Chang limestones. Between Bang Lum Sum and Ban Koh Ipuk the massive dolomitic limestones were seen on top of the Si Chang limestones, which show perfect bedding planes and strike E-W, dipping to the south at forty degrees to the horizongal, while the general strike of the fossiliferous limestones is NNW.

However, at the two mentioned hills northeast of the town of Kanchana Buri, Si Chang limestones strike N 35° W and dip easterly at 30 degrees. Also, while the fossiliferous dolomitic limestones

do not possess any rocks above them, being covered quite unconformably by Tertiary and Triassic strata, Si-Chang limestone are overlain by crystalline quartzites. At Kao Hua Larn, for example, the limestones dip more steeply (68°) into a bed of calcareous schist. On top of the schist is then a quartzite which shows crystals of quartz.

Along a N 50° W direction northwardly from this point these limestones may be seen to crop out all the way. They were found at Pu Lieb village and Kao Chon Kai. This same direction when produced southeastwardly would pass through Potaram in Rajburi, where probably the same rocks crop out. Koh Si-Chang would indeed be along this same line.

In age, Si-Chang limestones are decidely pre-Devonian. Now in Thailand, rocks down to Lower Cambrian had been discovered but they are not wholly crystalline like Si-Chang limestones. Below the Permo-Carboniferous limestones are formations ranging from Devonian to Cambrian but the unconformities between them are not as serious as between the Permo-Carboniferous limestones and Si-Chang limestones. These latter rocks seem to be the basement above which all fossiliferous rocks had been deposited. They are therefore classed as pre-Cambrian in age.

Now, relation between Sri-Raja series and Si-Chang limestones is still unknown. We, however, found thick beds of quartzites above Si-Chang limestone in Kanchana Buri but these are not the same as quartzites of Sri-Raja series. The inherent westerly dip of Sri-Raja series and of Si-Chang limestones points to the former being older. Now, it has been said that intrusions of gneissic granites intervene between the two formations, therefore the question of relative age should be left open for the present.

*c. Gneisses and Schists*

It had been mentioned that gneissic granites intruded Sri - Raja series and Si Chang limestones. These may be studied all along the eastern coast from Kao Pra Bart in Cholburi to Lam Chabang in Sri-Raja. At Kanchana Buri gneissic granites crop out at Ban Lard Yah and were seen to intrude the Si-Chang limestones at Kao Chon Kai and Kao Pu Rang, so that at Kao Chon Kai a zone of contact metamorphic minerals had been developed in the limestones. Similar occurences may be seen at Doi Sutep, in Chieng Mai and at Bang Pra, in Cholburi. At the contact the gneisses developed schistose texture and appear like mica schists.

The gneissic granites are of wide occurences. They form, with other basic gneisses and mica schists, a formation by themselves. In Kanchana Buri they were found to intrude only the Si Chang limestones, but not the upper quartzites. All rocks of Sri-Raja series had been affected by their intrusions.

Lithologically the granite gneisses are of from fine to medium-grained, ordinary to acid, granites. The texture is definitely gneissic though at few places the rocks do look like ordinary granites. They, however, often appear banded and with augen texture. Rocks intrusive into the gneissic granites are pegmatites which often carry large crystals of quartz, felspar tourmaline muscovite, and rarely, biotite. Arsenopyrite and beryl are sometimes found. Of lesser importance are aplites but they are seldom found. The pegmatites do not carry any economic metallic minerals but it is worthwhile to look for pottery felspar and beryl in them. The granite gneisses are the only granites which carry large muscovite books in their pegmatites. In Late - Cretaceous granites which are tin - and tungsten - bearing, there are also numerous pegmatite veins intruding the granites but minerals in such veins are not as large as those found in Pre - Cambrian pegmatites. Therefore, at present, prospectors have been quite

well aware of the possibility of finding good mica in the areas af Pre-Cambrian gneisses. Samples of large books of muscovite had been sent from Doi Sutep and Nakorn Sritamaraj. These measures 5×5 inches but are of low grade, being dug out from decomposed zone. However large crystals of felspar are quite common in the Pre-Cambrian pegmatiies and Thailand can be sure of her felspar supply, should her ceramic industry be developed.

The Pre-Cambrian granites seem to have phases of differentiation just as the Late-Cretaceous. At Hua Hin, the gneisses seem to be of the biotite granite variety, being free from muscovite and the felspar appears large and of augen texture. It is not difficult at all to imagine the original porphyritic biotite granites being squeezed by pressure into Hua Hin gneisses. Also the biotite gneisses yield sands high in ilmenite just as ordinary Late-Cretaceous porphyritic biotite granites. Also the biotite gneisses have their acid phase just as the porphyritic biotite granites are associated with the muscovite-biotite granites which often contain accessory tourmaline. Cholburi is the place where very acid gneisses may be studied. These acid gneisses are something very much like the stanniferous muscovite-biotite granites of southern Thailand, but the muscovite gneisses do not yield even traces of tin and tungsten minerals,

The Pre-Cambrian gneisses had suffered severe folding and sometimes they even appear bedded in appearances. The gneisses are sometimes stretched strongly into rocks very much like schists. These may be seen at Doi Sutep. The stretching is along a NNW to NW direction and this seems to be persistent in many areas of Pre-Cambrian rocks at great distances apart. The pegmatite veins are also parallel to the gneissic planes and they dips at 30° to 45° to the south. This stretching of the gneisses or gneissification seem to have taken place at the close of the Paleozoic era and to have affected all rocks up to the Permian.

Often found with the granite gneisses are basic or intermediate gneisses. These rocks are of rare occurrences but they are quite characteristic of the Pre-Cambrian igneous activity. The rocks appear as diorite gneisses and seem to be "interbedded" with the acid gneisses. They are "folded" or squeezed along the same direction and may be seen at Kao Rad in Pnas Nikom and at Ban Makork in Phyuha Kiri.

Also found inseparable with the granite gneisses are green micaceous and sericitic schists. These have been found at Ban Makork in Phyuha Kiri and at Ban Peh in Rayong. The schists are wholly crystalline and show signs of being intruded by the gneisses. In fact, the schists form a series by themselves and they seem to be on top of the Pre-Cambrian formations; but reference has been made to them because at the two places mentioned and at numerous other places, there have been reports on "gneisses and schists" showing that the two rocks have been considered as forming one system altogether.

We now come to the most controversial point in Thai geology, the age of the granite gneisses. That all the gneisses are of the same age is without any doubt. They have been found to intrude Si Chang limestones, Sri-Raja Series, schists and quartzites, all considered to belong to the the Pre-Cambrian age. They have, however, never been seen to intrude rocks of any known age, like the Permo-Carboniferous limestones. All the Triassic rocks are free from their actions. These seem to be some proofs of their occurrences before the Paleozoic era but extensive searches do not yet reveal the occurrences of Paleozoic or Mesozoic rocks resting on them; therefore the age of the granite gneisses still remain unsettled.

Also the granite gneisses do appear in many phases of differentiation like the Mesozoic granites which are tin-bearing in some places. The most doubtful case is when the two granites lie side by side. In the provinces of Rayong and Cholburi, there are wide expanses of granite gneisses and porphyritic biotite granites of Meso-

zoic age occuring side by side and the porphyritic granites are not tin - bearing. But at Kao Phra Bart in Cholburi, the writer was lucky enough to have found intrusions of the porphyritic biotite granites into the acid muscovite gneisses. The porphyritic granites are still just as they appear in the main mass at Kao Keo but the gneisses had suffered refusion into much coarser texture and had been intruded by innumerable pegmatite bodies, so that the whole of the gneisses near to the instrusions had turned into rocks not unlike pegmatites. This is then a decided proof that there are at least two granites of different ages in Thailand.

Also at **Koh Tuk Kare** in the island of Puket there is a bed of pebbly slate alleged to be of Lower-Cambrian age and some pebbles of the pebbly slate are of non - gneissic, tourmaline granites. Now as the writer had said, gneissification began at the close of the Permian age; therefore the Cambrian era must be free from gneissification. The Pre - Cambrian granites then would have formed pebbles in the Cambrian sea as granite pebbles and not as gneiss pebbles. These, being enclosed in argillites completely, would have survived gneissification to this day. The occurrence of granite pebbles in the Lower - Cambrian slates at Puket then conforms with the writer's idea as regards the Pre - Cambrian age of the granite gneisses.

*d. Kanchana Buri Quartzites*

Quartzites from a broad belt of hills east of the town of Kanchana Buri and they occupy the western rim of the Great Central Plain as far as Utai Tani. There they seem to cross over to the eastern rim of the plain and have been seen at Chai Nard and Ta Klee. Further east of Ta Klee they give way to Permo - Carboniferous limestones.

They have also been found all over Thailand, except on the Korat Plateau. In the north they crop out west and east of Chieng Mai and became the floor on which subsequent Permian deposits had been deposited. In the south they are in contact with gneisses at

Pran Buri and at Tublee on the sides of the Kraburi river, they have been seen underlying Puket series of Lower - Cambrian age.

Lithologically, they are principally of silica and appear so highly metamorphic that at many places they appear as aggregates of quartz crystals. They are interbedded with one bed of marble with perhaps, one bed of highly carbonaceous shale or schists.

At Kao Hua Larn in Kanchana Buri, the quartzites rest on Si-Chang limestones with an angular unconformity and there is an intervening bed of ten metres of calcareous schists. The interbedded stratum of marble appears as metamorphic argillaceous limestones about one hundred metres thick and is situated not far above the calcareous schist which occurs on top of the Si Cnang limestones.

The highly barbonaceous shales or schists are not found in Kanchana Buri. At Pranburi one such bed in quartzites had been metamorphosed by acid gneisses into graphite schists. Near Doi Nang Ma in Chieng Mai probably the same bed was seen in quartzites of Doi Sked. The carbonaceous shale of Tub Lee is also found in quartzites and this rock looks so black that it glistens like coal.

Regionally, the Kanburi quartzites were folded along the same direction as Si-Chang limestones were folded along the same direction as Si-Chang limestones and Pre - Cambrian gneisses, that is along a NW to NNW direction. In the provinces of Kanchana Buri they seem to be the floor on which Permo - Carboniferous limestones had been deposited and therefore their Pre - Paleozoic age in sure enough.

*e. Pnom Sarakarm Schists*

The reason that the strata above Kanchana Buri quartzites have been called Pnom Sarakarm Schists is two fold. One is that at the same locality the schists have been found to be cupriferous over wide areas without any signs of igneous activity nearby; and the second is that exploitation of this copper field had robbed the writer so

much energy and patience that he could not forget the schists until the end of his life.

Lithologically the formation is wholly an argillaceous series with only occasional small beds of quartzite intervening. The rocks appear as phyllites and schists and range in colour from dark silvery black through green to micaceous white. South of Chieng Rai, the schists and phyllites are interbedded with many beds of "graphitic" schists and these keep the prospectors quite busy, only to have found after a simple experiment that there is very little amorphous carbon in the schists.

The schists seem to rest conformably on top of the Kanchana buri quartzites but these are to be seen only at Chieng Mai when one makes a trip from Doi Sked to Vieng Pa Pao. Even then, this is not so sure, as W. Lee himself had placed the schists under the quartzites. However, the writer had actually made the trip, W. Lee only made assumptions based on other facts. The writer is also in a dilemma and this is due to insufficient field work. If one travels from Khoon Tarn to Lampang, one may see, adjacent to the biotite granites there, Pnom Sarakarm schists and at Pang Pua, a bed of sandstone dipping eastwardly. A similar sandstone which appears as compact and dense as quartzite crops out again in the mountainous region east of Lampang. There are, of course, cases of quartzites overlying schists as in the case of Sri-Raja Series and Rajaburi schists and quartzites but these seem to be of different age altogether. At Kao Kob in Pak Nam Poh the schists actually overlie quartzites.

At Utradit the green schists seem to be the crystalline floor on which all subsequent beds had been deposited. These green schists sometimes occur in association with gneisses mentioned in the former section and may be studied at may points e. g. at Ban Makork in Phayuha Kiri and at Ban Peh in Rayong.

In addition to thin quartzite beds, the schists contain at one place a six-inch bed of barytes. Numerous milky white quartz veins are seen in them but they are quite barren.

It is only very rare for the Pre-Cambrian schists to show less metamorphism and appear slaty or phyllitic in texture.

But in all areas of crystalline schists, phyllites of the same age may be found side by side. Usually the schists are wholly crystalline and consist principally of small grains of quartz in separate laminae interlaminated with muscovite. The accessory minerals are almandine garnets, epidote, kyanite and magnetite.

Similarly, the schists had been subjected to folding along a NW to NNW direction. In Vieng Pa Pao the stretch is definitely along the north and south axis. The dip is mostly to the east and the schists are quite contorted in many places, even small samples will show the effect of this contortion. The veins of quartz had also been olded with the schists and most of them are parallel to the schistosity plane.

*f. Areas of Pre-Cambrian formations.*

Years of geological explorations have revealed the extensiveness of Thai Pre-Cambrian rocks. Only the Korat plateau is devoid of these formations, being underlain principally by Triassic rocks. In this book only very brief descriptions will be given on geological details of any place as this requires accurate and more extensive prospecting works. The writer had, however, only spent a few hours on every formation encountered during his Economic Survey of the country.

(1) Yala-Bannangstar area: This consists of biotite gneisses with pegmatite veins, seen at the cross road to Bannangstar. The gneisses occur as a range of hills parallel to Yala-Betong road. Near the district of Bannangstar, these give place to quartzites and contorted

schists with the quartzites underlying. Further west to the sub-district of Tum Talu, these old rocks are overlain by paleozoic sandstones, shales and limestones. The quartzites and schists were intruded by stanniferous granites, and probably these younger granites have come into contact with the old gneisses also.

(2) Nakorn Sritamaraj Area: The gneisses and schists are found at the sub-district of Ta Dee. There the schists are wholly crystalline and the gneisses consist of two mica granites with tourmaline as an accessory mineral. There are numerous pegmatite veins in the gneisses and they show large felspar and mica crystals with beryl as a rare constituent. Stanniferous granites seem to have intruded this old formation on the west. Sands derived from the granite gneisses are high in almandite, ilmenite and monazite. This last mineral seems to be a faithful associate of Pre-Cambrian gneisses. The gneissic plane is definitely aligned along north and south direction.

(3) Sichol Area: North of the district office of Sichol in Nakorn Sritamaraj is a group of hills which are wholly of biotite gneisses. They are quite metamorphic, some even appear to have a schistose texture.

(4) Hua Hin Area: Hua Hin is well known as a health resort in summer. The country rocks of this sub-district are gneisses, quartzites and schists but the main rocks are granite gneisses. The main mass of the gneisses is of biotite granites and there are innumerable pegmatite veins in the mass. Permo - Carboniferous limestones are seen on both sides of the gneiss outcrop and the trend of the gneisses is from NW to NNW. The gneisses extend only as far as Petchburi river where the formation ends up and is capped by sandstones of Permo - Carboniferous age. Southeastwardly the gneisses come down as far as the coast and vanish under the sea. The sea sands contain ilmenite, almandine and monazite as heavy concentrates, just as found in Nakorn Sritamaraj.

(5) Rajburi Area: Quartzites underlain by schists probably belonging to Sri - Raja series crop out as a line of small hills near to the town of Rajburi. They are associated with sandstones and shales of Permo - Carboniferous age and Permo - Carboniferous limestones may be seen flanking their outcrops on both sides.

(6) The Great Central Plain: Wide areas of Pre - Cambrian rocks occupy the rims of Great Central Plain drained by Chao Phya, Meklong, Tajeen and Cha Cherng Sao river. The old rocks found at rims range from Si-Chang limestones to Cholburi granite gneisses and Sri - Raja series. In the Gulf of Thailand the Si-Chang limestones appear as an island called Koh Si-Chang. Up north a great expanse of quartzites covers an area from Supan Buri to as far as Chai Nard. The range of gneisses and schists which begins from Phyuhakiri and ends up at Paknampoh is within this great area of old rocks.

(7) Utradist Area: This is also a great area of metamorphic schists seen along Nan river. The schists seem to crop out as far as Sukhotai and join up with the schists outcrop of the province of Tark.

(8) Chieng Mai - Tark Area: This rather long and broad area of gneisses, quartzites and schists extends from Chieng Rai as far as Tark. It probably joins the area of old rocks seen in the great Central Plain at Paknampoh. The outcrops of the old rocks were intruded by Cretaceous granites right from the town of Chieng Rai to as far as Muang Tark and the highest mountains within this region e.g. Doi Sutep, are of granite gneisses.

(9) Rayong - Chacherngsao Area: Granite gneisses, crystalline mica schists and subordinate quartzites occupy a vast area from Pnom Sarakam to as far as Koh Smed in the sea near the town of Rayong. They seem to be connected to the old rocks of the Great Central Plain, were it not for the numerous intrusions of Cretaceous granites separating the two areas apart.

(10) Cholburi Area: Pre-Cambrian rocks there comprise of granite gneisses and rocks of Sri - Raja series, the description of which has been given elsewhere.

*Correlation with neighbouring Geology.*

Pre - Cambrian rocks have never been reported from Malaya. Scrivenor said that Malayan quartzites and schists belong to the Triassic system, being matamorphosed shales and sandstones. However, the writer thinks that Pre - Cambrian rocks may be found in Malaya on the frontier between Betong and Toh Moh as this will be a continuation of Yala gneisses, schists and quartzites.

In Annam, especially in Cochin China there are vast areas of gneisses and schists; and near to Rayong, the gneiss - schist zone is an outcrop of gneisses and schists at the celebrated Ruby - Sapphire deposit, Bor Pailin in Cambodia.

The granite gneisses, intruding Kanchana Buri Si-Chang limestones at Lard Ya, seem to have appeared as the Martaban system in Burma, which is indeed on the same line of strike as Kanchana Buri Pre - Cambrian rocks. The Martaban system had been described by H.L. Chibber as consisting of gneisses and schists. The continuation is, however, only an inference as Permo - Carboniferous limestones intervene in between and it keeps the two occurrences of gneisses quite well apart. The strata of schists and phyllites described as the upper Pre - Cambrian also appear to coincide with the Chaung Magyi series of Burma.

( *To be continued* )

# ABSTRACTS

*Some Observations on the Morphology of Rice. (in Thai).*

Dr. P. Punyalaksana. Department of Agriculture, Bangkok.

*Collected Papers, Science Conference 1949, p.1., The Science Society of Thailand.*

The article is a preliminary report on an attempt to collect data on age comparison, height and spread of the stalk, colour, shape of heads and grain density of rice varieties in Thailand including those from U.S.A., Java, India, and the Phillipine Islands. One of the local varieties the Sai Bua Vai gives the grain density up to 1.463. Those of two outstanding varieties from Java, the Benguwan and the Brondol proctila are 1.356 and 1.343 respectively.

S.S.

★

*A Note on Kwao Keur, the Rejuvenating Plant. (In Thai).*

M.C. L. Kasemsanta and K. Suvatabandhu. Department of Agriculture, Bangkok.

*Collected Papers, Science Conference, 1949, p. 20., The Science Society of Thailand.*

The plant locally called Kwao Keur the tuber of which contains an unidentified oestrogenic substance, was described as *Butea superba Roxb.*, by A.F.G. Kerr ( J. Siam Soc., Natural History Bulletin, 1932, Vol. 8, p. 336). The leave of the Kwao Keur resembles that of

*Butea superba* but the latter gives no tubers. From the study of flowering materials it is suggested that Kwao Keur is not *Butea superba* but an undescribed species of Pueraria.

S.S.

★

*An Investigation on the Insulin-like Principle in Plants.*
*I. A Preliminary Report on the Insulin-like Substance in the seeds of Lagerstroemia speciosa. (In Thai).*

S. Rugtawat, C. Sambhandharaksa and K. Bunnag.
School of Pharmacy, University of Medical Sciences, Bangkok.

*Collected Papers, Science Conference 1949, p. 169., The Science Society of Thailand.*

The dry seeds of *Lagerstroemia speciosa* is well ground and the active principle is extracted by boiling water. After removal of tannin the aqueous extract is evaporated to dryness. The oral administration of the aqueous solution of the crude extract shows marked blood sugar reduction in the rabbit. Isolation of the pure active principle is still attempted.

S.S.

★

*An Experiment on Keeping Poultry, using the California Battery System. (In Thai).*

Luang Suvan Vachokasikich. The University of Agriculture, Bangkok.

*Collected Papers, Science Conference, 1950, p.1., The Science Society of Thailand.*

The California Battery System was used in an experiment on keeping poultry at Kasetsatra (Agriculture) University. Results were

given and discussed. It was concluded that inspite of the higher cost of this system it would be successful and profitable in Thailand.

Y.B.

★

*Response of Rice of Different Maturity Dates to Fertilizer. (In Thai).*

P. Sasriplin. Department of Agriculture, Bangkok.

*Collected Papers, Science Conference, 1950, p. 22., The Science Society of Thailand.*

Five varieties of rice of different maturity dates were investigated. Results were as follows:

1. The fertilizer increased yield, height of plant tillering, number of panicles per hill, and number of seed per panicle of all varieties tested.

2. The varieties differed from one another in all characters mentioned.

3. The interaction of varieties and fertilizer was found highly significant in yield and number of panicles per hill.

Y.B.

★

*Cooking Qualities of Some Varieties of Non-Glutinous and Glutinous Rice. (In Thai).*

S. Pukavesa. Department of Agriculture, Bangkok.

*Collected Papers, Science Conference, 1950, p. 60., The Science Society of Thailand.*

1. After cooking, the non-glutinous rice absorbed water 160-290 per cent, increased 160-390 per cent in volume, while the glutinous rice absorbed 160-270 per cent and increased 120-345 per cent in volume only.

2. Duration and method of storage, cooking procedure considerably affected the cooking qualities.

Y.B.

★

*Dormancy in Rice.* (*In Thai*).

Dr. P. Punyalaksana. Department of Agriculture, Bangkok.

*Collected Papers, Science Conference, 1950, p. 67., The Science Society of Thailand.*

Resting period, the time between the ripening and the germination of the grain, was studied among 39 varieties of rice. It was found to vary from 72 to 149 days. Dormancy and rate of growth were not necessarily related.

Y.B.

★

*Germination of Orchid Seeds.* (*In Thai*).

K. Chalavicharana. Department of Agriculture, Bangkak.

*Collected Papers, Science Conference, 1950, p. 109., The Science Society of Thailand.*

Sowing of orchid seeds in agar media was fully described and demonstrated together with six different formulae listed. The various techniques given, being of great value to amateurs and

hobbyists, dealt into minute details otherwise found only in the voluminous compilations from many different authors.

V.N.

★

*Avian Leucosis Complex.* (*In Thai*).

M.R. C. Devakul. Faculty of Veterinary Science, Bangkok.

*Collected Papers, Science Conference 1950, p. 203., The Science Society of Thailand.*

The 'haemorrhagic form' of visceral lymphomatosis type in avian leucosis complex was observed as a definite entity during the investigation of an outbreak of poultry disease around Bangkok. It was characterized by intramuscular haemorrhages over the breast, thighs and around the joints resembling purpura haemorrhagica. Haematological confirmation was also made. Microscopically it resembled pathognomonic lesions of avian monocytosis. The blood films showed both erythroblastosis and granuloblastosis. Zenker's hyalinization of the muscle eosinophilic intranuclear inclusion of the Langerhans islets, protein precipitation in the Bowman's capsule, hyaline casts, pseudo-giant cells and crystalloid radiating casts in the renal tubules characteristic in avian monocytosis were absent. It has been suggested that the classical visceral lymphomatosis should be designated 'leucocytic form', and the one formerly described as erythroblastosis or erythrogranuloblastosis, the 'haemorrhagic form'. Both forms could be differentiated microscopically though with some overlapping.

S.S.

★

*Saanen Goats.* (In English)

Luang Suvan Vachokasikich, and L.M. Thuan Komkris.
University of Agriculture, Bangkok.

*Collected Papers, Science Conference 1949, p. 13; 1950, p. 1., The Science Society of Thailand.*

Experiments on imported Saanen goats, Native goats and cross-bred Saanen-Native goats, were made at Bangkhane, with the following results:—

| | Average total yield of milk, Kg. | Average lactation period, days | Average daily yield Kg. | Average butterfat percentage |
|---|---|---|---|---|
| Saanen Does | 816.078 | 393.6 | 2.073 | 3.36 |
| Native Does | 321.842 | 279.8 | 1.150 | 6.10 |
| Saanen-Native Does | 517.234 | 279.8 | 1.913 | 4.64 |

The improvement on the native goats by cross breeding Saanen goats is promising.

R.S.

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นางสมพงษ์ อำพล ผู้พิมพ์ผู้โฆษณา ๒๔๘๕