MINERAL RESOURCES OF BURMA

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# THE MINERAL RESOURCES OF BURMA

BY

H. L. CHHIBBER

D.Sc., Ph.D., D.I.C., F.G.S., F.R.G.S.

Sir H. V. Cobb Gold Medallist; Geological Survey of India; formerly Head of the Department of Geology and Geography, University College, University of Rangoon and Chairman of the Board of Studies and Board of Examiners in Geology and Geography, University of Rangoon; sometime Assistant Professor of Geology and Member of the Faculty of Science and Board of Studies in Geology of the Benares Hindu University

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TO

MY WIFE

SHRIMATI VIDYA VATI CHHIBBER

in appreciation of her affectionate spirit of self-sacrifice and willingness to help me in my small endeavours.

# PREFACE

IT was originally intended to publish the account of the geology and mineral resources of Burma in one volume, but later on it was found advisable to issue it in two parts. It really seems to have been the best course, as Burma, from the mineral resources point of view, is undoubtedly the most important province of the Indian Empire. The two books are complementary to one another, but the stratigraphy of important areas is sketched in the present volume, and petrographical detail is included where this has some bearing on the genesis of the mineral deposits. The present volume aims at giving an up-to-date account of almost all the important mineral deposits and mineral industries of the country, and some parts have been written entirely from personal observation. The chapter on jadeite may appear too lengthy, but that is perhaps justifiable. In spite of my best efforts to reduce the account to a reasonable size, I could not shut out the mental picture of the area I had before me. I spent about two years in the field alone in the Jade Mines area, and the same amount of time has been spent in the laboratory study of the rocks. It may be added that the chapter contains only the gleanings of my observations on the jadeite deposits. Similarly the chapter on amber offers but a summary of my work on these deposits, and also includes some recommendations with a view to improving the industry, and I feel myself lucky in removing several erroneous notions prevailing about these deposits.

In Chapters X and XI on tin and tungsten, the new areas which may be explored profitably have been briefly indicated. I feel almost confident that large areas which could be worked profitably for these metals lie unexplored in the somewhat remote jungles of the Tavoy and Mergui districts, especially in the latter. The chapter on petroleum is contributed by Dr. L. Dudley Stamp, to whom I am grateful.

With the present boom in the price of the noble metal, I trust the chapter on gold will prove helpful to those who wish to exploit it, especially in the north. I think the salt industry can afford considerable scope to the at present unemployed youth of Burma, who with improved boiling methods, etc., as devised by the Government Salt Department, can earn their livelihood comfortably. I had the opportunity of discussing the subject with Mr. E. G. Robertson, Chief Collector of Salt Revenue, Burma, who also shares this belief. A considerable quantity of salt is imported annually into Burma from foreign countries. Would it not be worth while to keep that wealth within the country and the Empire? Besides winning salt from the sea, the brine springs of the north, *e.g.* those of the Myitkyina district, also deserve attention.

It is interesting to note that the iron-ore deposits of the Northern Shan States are already finding use as a flux in the lead-silver smelters at Namtu; but unfortunately the coal and lignite of Burma are too friable to be worked as such, though the time may arrive when they can either be briquetted or distilled. In Chapter XIII on miscellaneous minerals, several of minor importance have been briefly described. The establishment of a glass industry at Mergui perhaps deserves consideration from those interested.

In a mainly agricultural country the importance of soils can hardly be over-emphasised. Instances are not wanting, *e.g.* in the north of Burma, where the cultivation of paddy and sugarcane on haphazardly selected serpentine soil and on the Tertiaries, in spite of costly manuring experiments, was a failure; while only a few miles away, the soil, indeed, proved ideal. I am grateful to Dr. S. P. Aiyar for discussing the chemistry, etc., of the soil-groups of Burma in Chapter XIV. Valuable suggestions in connection with this chapter were made by Professor G. W. Robinson of University College, Bangor, and by Dr. E. M. Crowther of Rothamsted Experimental Station.

Some of the information contained in the last chapter was collected by visits to the quarries, etc., of the different districts, and a preliminary communication on the subject was read before the Geology Section of the Indian Science Congress, held at Calcutta in 1928.

Those whom I have the privilege of knowing personally are aware that the publication of the observations embodied in this work, and carried on almost continuously from the year 1924 to the end of 1931, was delayed by serious illness contracted in some of those disease-infested jungles of Burma. Later, two years were spent in London in rewriting the work and also in making further laboratory investigations; yet the author's labours will not have been in vain if the volume proves of any assistance to those who are interested in the development of the mineral resources of Burma.

Finally I have very great pleasure in expressing my indebtedness to Dr. A. K. Wells of King's College, London, who kindly undertook to see the book through the press on my departure from London. Acknowledgments have also to be made to those named in the companion-volume who so kindly read the proofs of parts of the book, more especially to Dr. J. Coggin Brown for his kindly interest and encouragement, both in the field and in the laboratory. As a student of Indian and Burmese geology, I should like to express my appreciation of the Bibliography of Indian geology and physical geography by T. H. D. La Touche.

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# CHAPTER I

## Geological and Geographical Distribution of Mineral Deposits.

BURMA is very rich in mineral resources, and deposits of petroleum, lead, silver and zinc, tin and tungsten ores, rubies, sapphires and spinels, jadeite and amber, gold, coal, etc., occur in different parts. It has been shown recently by J. Coggin Brown that the mineral deposits of Burma can be classified into seven geographical regions, each of which is associated with certain particular types or groups of rocks. Each group is marked by its own diastrophic events, when its mineralisation was brought about. Beginning from the east, the Author recognises the following six groups:

(1) Shan-Yunnan region. This group is largely composed of sedimentary rocks ranging in age from the Cambrian (?) to Cretaceous. Igneous rocks are not common. The mineral association is essentially a sulphidic one, comprising argentiferous galena, sphælerite, chalcopyrite, pyrite and stibnite. The occurrence of coal associated with the Jurassic rocks is also noteworthy.

(2) The Mogok-gneiss region is built of gneisses and igneous intrusive rocks with crystalline limestones. The crystalline limestone carries mainly the celebrated rubies, spinels and other precious stones, and also graphite.

(3) The Tenasserim region is composed of the quartzites and argillites of the Mergui Series, which have been invaded by granite. The important minerals characteristic of this region are cassiterite and wolfram, with smaller amounts of molybdenite, bismuthinite, chalcopyrite, pyrite, arsenopyrite, zinc-blende and stibnite.

(4) The Central Belt of Burma and the Arakan Coastal strip, including the islands of Ramri and Cheduba, are composed of

Tertiary rocks. They contain hydrocarbons, viz. petroleum, coal and amber.

(5) The Mingin group occupies a small but unique area, which is built of volcanic tuffs, andesitic breccia and conglomerate. Granodiorite with tourmaline pegmatites is intrusive into the volcanic rocks. Gold-telluride quartz veins, containing chalcopyrite, pyrite, galena, franklinite and altaite, are associated with the volcanic rocks.

(6) The Arakan-Naga region includes the serpentinised peridotites which carry chromite, native copper, chalcocite, chrysotile, steatite and magnesite. In the Myitkyina district jadeite is intrusive into these ultrabasic rocks.

The Plio-Pleistocene and Recent deposits occurring all over Burma contain lignitic coal deposits in the Northern Shan States and the Mergui district, also oil-shales in the Amherst and Mergui districts. With these may also be included the residual iron ores of the Shan States and the Kamaing subdivision, the manganese ores of Meiktila, the laterite of Lower Burma, the gem-gravels of the ruby mines, the gold and platinum placer deposits of the Irrawaddy, Chindwin and other rivers, the eluvial and alluvial wolfram and cassiterite deposits of Tenasserim.

The geographical groups, with their stratified and igneous rocks and the chief associated minerals, are shown in the table on the opposite page.[1]

Geologically, it will be noticed from the table that the rubies, sapphires, spinels, etc., are associated with the Archaean gneisses and crystalline limestone. Next follow the rhyolite and rhyolite tuffs of Bawdwin, which carry ores of lead, silver, zinc and copper. With the serpentinised peridotites of late Cretaceous to early Eocene age of the Arakan-Naga Hill ranges chromite, native copper, chalcocite, platinum, steatite, magnesite and jadeite are associated. As a complementary phase of this activity, the granites of the Eastern Hill ranges were erupted, and carry the ores of tin, tungsten, etc., extending from the Mergui district in the south to the Kyaukse district in the north. Later on, associated with the early Tertiary

[1] Modified from Dr. Coggin Brown, *Rec. Geol. Surv. Ind.*, vol. lvi, 1926, p. 66.

| Geographical group. | Sedimentary rocks. | Igneous rocks. | Chief minerals. |
|---|---|---|---|
| (1) Shan-Yunnan - | Cambrian (?) - Cretaceous | Rhyolite and rhyolite tuffs at the base of the Ordovician. | Argentiferous galena, zinc-blende, chalcopyrite, pyrite and stibnite. |
| (2) Mogok - - - | Crystalline limestones. | Archaean gneisses, intrusive granite, syenites, nepheline rocks, etc. | Ruby, sapphire, spinel, graphite. |
| (3) Tenasserim with its continuation to the north. | Argillites, slates, quartzites. | Granites. | Wolfram, cassiterite, molybdenite, bismuthinite, native bismuth, chalcopyrite, arsenopyrite, pyrite, zinc-blende, stibnite. |
| (4) Mingin - - - | — | Volcanic tuff, breccia, conglomerate with granodiorite and pegmatites. | Gold, chalcopyrite, pyrite, galena, franklinite, altaite. |
| (5) Central Belt - - | Eocene to Recent. | — | Petroleum, natural gas, coal, amber. |
| (6) Arakan-Naga - | Triassic, Cretaceous and Eocene rocks in part. | Serpentinised peridotites, gabbro and microdiorites. | Chromite, native copper, chalcocite, platinum, gold, chrysotile, steatite, magnesite and jadeite. |

volcanic rocks of the Wuntho region, gold, chalcopyrite, pyrite, galena, altaite, etc., were formed. In the Central Belt in Tertiary times, petroleum, natural gas, oil-shales, coal and amber were formed. In brief, during Archæan, Cambrian (?), late Cretaceous-early Eocene and early Tertiary times huge diastrophic movements occurred in Burma, accompanied by igneous activity, which brought about the mineralisation indicated above. Of course, petroleum, oil-shale, coal and amber are associated with the sedimentary rocks, and are undoubtedly of organic origin.

Tables showing the output of important minerals, together with their respective values for the quinquennium 1926–1930, are appended on the opposite page.

TABLE SHOWING OUTPUT OF MINERALS FOR PERIOD 1926-1930.

| | 1926. | | 1927. | | 1928. | | 1929. | | 1930 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity. | Value in Rupees. | Quantity. | Value in Rupees. | Quantity. | Value in Rupees. | Quantity. | Value in Rupees. | Quantity. | Value in Rupees. |
| Gemstones (Rubies, Sapphires and Spinels) | 105,571 carats | 4,66,772 | 39,590 carats | 2,79,834 | 40,380 carats | 1,77,512 | 43,650 carats | 1,81,760 | 30,090 carats | 1,31,155 |
| Jadeite - - - | 1,203·75 cwts. | 2,34,456 | 2,227·03 cwts. | 2,39,064 | 2,844·5 cwts. | 2,85,984 | 3,450·95 cwts. | 2,77,356 | 1,498·95 cwts. | 3,60,487 |
| Amber - - - | 39·5 cwts. | 21,420 | 70·5 cwts. | 27,180 | 29·4 cwts. | 12,020 | 19·585 cwts. | 6,080 | 2·073 cwts. | 730 |
| Iron Ores - - | 55,502 tons | 58,122 | 56,204 tons | 56,204 | 74,813 tons | 74,813 | 41,001 tons | 1,32,980 | 33,454 tons | 1,04,354 |
| Gold - - - | 146·617 ozs. | 12,618 | 59·667 ozs. | 4,947 | 71·38 ozs. | 5,807 | 36·112 ozs. | 2,532 | 56·612 ozs. | 4,450 |
| Lead, Silver, Zinc and Copper Ores | 362,880·3 tons | 1,13,74,006 | 454,733·5 tons | 1,08,15,703 | 446,862 tons | 1,19,56,862 | 468,023·1 tons | 1,21,25,478 | 530,165·1 tons | 1,41,10,267 |
| Petroleum - - | 250,040,471 gallons | 9,20,90,865 | 245,904,044 gallons | 5,22,15,324 | 262,187,263 gallons | 4,91,19,173 | 253,400,524 gallons | 5,36,34,977 | 256,554,026·83 gallons | 4,23,62,916 |
| Tin Concentrates - | 2,772·10 tons | 48,41,076 | 3220·48 tons | 54,99,216 | 3,521·67 tons | 51,58,726 | 3,668·65 tons | 49,48,590 | 2,753·10 tons | 32,87,929 |
| Tungsten Ore - - | 754·1 tons | 3,80,213 | 165·788 tons | 86,848 | 444·76 tons | 86,848 | 1,059·60 tons | 12,32,620 | 1,452·08 tons | 10,75.583 |

# CHAPTER II

## GEMSTONES.

### RUBIES.

BURMA has long been celebrated for its gemstones, especially the rubies, sapphires and spinels, and has been the principal source of supply of these gemstones to the world. Though the date of the first working of the mines is quite unknown, there is, however, no doubt that the mines have been worked for many hundreds of years. One of the sons of Kun-Lung, the founder of the Shan dynasty, is said to have governed a State, in the sixth century A.D., near to which there were ruby mines and for which he paid an annual tribute of two viss (one viss= 3·65 lb.) of rubies to the Central Government. In 1597 the mines passed into the hands of the Burmese Kings, who seem to have kept a very firm hold on them. They were let out on lease for a fixed annual sum, and, in addition to this payment, there was in existence a law by which all stones above a certain size were regarded as belonging to the King, who also reserved the right to confiscate any mine which, for some reason or another, showed good promise, and to work it himself. One of the earliest references to the Ruby Mines is that of Ludovico di Varthema, who visited Pegu in 1496.

Caesar Fredericke, who visited Pegu in 1569, describes the King of Pegu as "Lord of the Mines of Rubies, Safires, and Spinels" and states that the idols of the court were studded with "most rare Rubies and Safires," and refers to the brisk trade then being carried on in rubies. The English traveller, Ralph Fitch, was the first to make reference to the mines, though neither of these travellers was permitted to visit them. Père Giuseppe d'Amàto was the first to give an authentic account. He describes the workings at Kyatpyen (22° 53′ 30″, 96° 28′) and the systems of mining then practised by the Burmese. This method may still be seen in operation in that neighbourhood. He says:

"The miners, who work at the spot, dig square wells, to the depth of 15 or 20 cubits, and to prevent the walls from falling in they prop them with perpendicular piles, four or three on each side of the square, according to the dimensions of the shaft, supported by cross pieces between the opposite piles.

"When the whole is secure, the miner descends and with his hands extracts the loose soil, digging in a horizontal direction. The gravelly ore is brought to the surface in a rattan basket raised by a cord, as water from a well. From this mess all the precious stones and any other minerals possessing value are picked out and washed in the brooks descending from the neighbouring hills. . . .

"The Chinese and Tartar merchants come yearly to *Kyatpyen* to purchase precious stones and other minerals. They generally barter for them carpets, coloured cloths, cloves, nutmegs and other drugs. The natives of the country also pay yearly visits to the royal city of Ava, to sell the rough stones. . . ."

*With the annexation of Upper Burma, Mogok was occupied* by the British in 1886. In October 1887 the Upper Burma Ruby Regulations (XII of 1887), framed to declare the law relating to rubies and other precious stones, came into force. By it the Local Government were empowered to notify the "stone tracts" and to make rules regarding the mining, cutting, possession, buying, selling and carrying of precious stones, and to grant licenses for these purposes. In November 1887 the Mogok stone tract was constituted. The history of the Burma Ruby Mines Company Ltd. is given in the sequel.

Rubies are known to occur in three important tracts in Upper Burma; but in all cases the original source of the gems is found to be a highly crystalline limestone. A fourth tract is reported to have been discovered in the Momeik State in 1913, but no definite information has been published yet. A stone tract is also known to occur within the State of Kengtung.

### Ruby Mines, Mogok, Katha District.

The Ruby Mines tract in the neighbourhood of Mogok, Katha district, has been the most important source of rubies in Burma. The geology of the Ruby Mines area has been described in the author's *Geology of Burma*, Chap. XI, and it is sufficient to note here that the rocks belong to the Archaean, and comprise a complex series of highly metamorphosed paragneisses, granulites and crystalline limestones invaded by veins of aplite and pegmatite. The crystalline limestones carry phlogopite and graphite, and less commonly forsterite, diopside, tremolite, chondrodite, pyrites, apatite, spinels and rubies. In this district the ruby-bearing crystalline limestones form a series of narrow, parallel, lenticular bands, distributed *en echelon* along the southern flanks of the range of hills extending from the neighbourhood of Mogok (22° 55′, 96° 33′), where the most productive mines are situated, to Thabeitkyin on the Irrawaddy, a distance of about 40 miles in an east-west line. The other important area is Katha, a village seven miles by road, west of Mogok. At the 42nd mile south of Kabaing on this road other mines are situated at Sakangyi and yield rock-crystal and topaz. In the Kin valley, through which the road passes at the 37th mile, gems are also known to occur. Another gem-bearing area lies about seven miles north-west of Mogok, and represents the now deserted cantonment of Bernardmyo. The workings, therefore, are confined to the eastern half of the calcareous zone, between Shwenyaung (22° 55′, 96° 19′) and Mogok, where the character of the limestone bands indicates that they have been subjected to a more intense degree of metamorphism than farther west, where rubies appear to be absent. The rubies found here are generally of a carmine, cochineal or rose-red colour, with a play of violet, but the most valuable are of the colour of pigeon's blood.

### Ruby Workings.

It has been found unprofitable to work the limestones for rubies owing to the relative scarcity of the gems. The native workings (Plate 1), however, as described by Barrington Brown and others, can be classified into the following three kinds:

PLATE I.

NATIVE GEM WORKINGS AT MOGOK.

Notice the lever arrangement used for hauling the débris.

(1) **Loodwin,** where fissures and hollows in the limestone, filled with detritus derived from its disintegration by weathering, are followed up and quarried. Small galleries or tunnels, just large enough for the men to crawl along, are made through the fissures and the softer or disintegrated parts of the rock, until a lode of decomposed limestone or a vein of gravel is struck. This earth or gravel is brought to the surface and carefully washed, and appears to be naturally concentrated, sometimes containing as much as 25 per cent. of rubies.

(2) **Hmyaudwin,** or cuttings driven into the rainwash covering the outcrop of the limestone on the hill slopes.

The Hmyau-working is a primitive system of hydraulic mining. An open cutting on the hillside is chosen, the lower end of which opens into a gully. Water channels are then constructed by digging trenches to conduct water from one of the mountain streams, often at a considerable distance along the hillside, to the cutting. The water is delivered at the top of the cutting, and flows away through a trench at the bottom, which forms a kind of sluice. The earth is excavated from the sides by hand and thrown into the sluice. The water, falling in a heavy shower on the earth, softens it and removes the clayey particles, while the sand and gravel are held by riffles placed across flumes at the lower end of the trench. This concentration is again puddled, the larger pebbles thrown away, and then the remainder is carefully searched for rubies and other precious stones.

(3) **Twinlons** are pits sunk in the alluvial deposits spread over the floor of the valleys, to reach the gem-bearing gravel, called *byon,* which generally lies at a depth of about fifteen to thirty feet. Bamboo levers on poles are then fixed round the mine, with rattan ropes and buckets attached, and these are used for hauling up the *byon*, or for baling the water from the pit (see Plate 1).

The fourth system of winning gem-stones is by washing the sand and gravel in the beds of streams. Sometimes a dam is built across a portion of the river, then, depending upon the depth, baskets of gravel are obtained either by hand or by diving.

The fifth method of working may be called quarry mining.

A limestone cliff is selected and the rock is detached by blasting, broken by hammers, and the enclosed rubies are chipped out. Owing to the crudeness of the methods the rubies extracted are somewhat damaged and the method therefore is not very popular.

### History of the Burma Ruby Mines Company.

The first lease was granted to the Burma Ruby Mines Company in 1889, at an annual rental of Rs. 3,15,000. A second lease came into operation in 1897, and a third one for a period of 28 years in 1904. The Company was required to pay an annual rent of Rs. 2,00,000 *plus* 30 per cent. of the net profits made each year. It was in about 1907 that the market for gemstones became depressed. The slump continued in subsequent years and the value of production, of which the annual average was £84,000 during the period 1904–8, fell to £63,272 between 1909–13 and to £41,817 during 1914–18; between 1919 and 1923 it rose to £60,660.

The Company went into voluntary liquidation in 1925, and such stones as have been won since that date are due in part to its letting out certain gem-bearing areas on a modified tribute system. The regrettable demise of this famous concern, after its chequered career of 36 years, is best quoted from J. Coggin Brown's *Note on the Mineral Production of Burma during the year 1925.*

"The Sinkwa Mine was closed during the year. The best parts of the Mogok and Katha valleys are reported to be approaching exhaustion, and the residue of ruby-bearing ground in these areas is said to be insufficiently rich to pay for extensive working. These mines are now let out to tributors who clean up patches of ruby-earth left in crevices and detached spots. The loss on last year's working has finally exhausted the capital of the Company, which has since decided to go into voluntary liquidation."

In the opinion of J. Coggin Brown the present condition of gem-mining in Burma is due to the cumulative effect of numerous adverse causes; but the exhaustion of gem-bearing deposits is not one of them. The Mogok Stone Tract occupies more than 600 square miles, and there are other valleys in the Stone Tract in which gems are known to occur, and which deserve fuller exploration than they have hitherto received, with the object of proving their value as hydraulicking propositions rather than as deposits to be opened up by costly and laborious hand methods.

## Methods of Working of the Burma Ruby Mines Company.

The Company systematically works the alluvial deposits covering the floor of the Mogok valley and the *byon* is washed by most modern appliances, which comprise the washing plants working at Mogok and Katha. Each plant consists of a washing mill, where the material is dumped over screens, through trommels and into washing pans. At the end of the day the heavy concentrate from the pans is placed in trucks with covers, which are kept locked. The concentrates thus obtained are now transferred to the sorting shed, where they are introduced into a series of trommels. The material larger than five-eighths of an inch is sorted by hand at the sorting table. The material which passes the finest meshing of the trommels is allowed to run to the dump and is sold to the villagers of Mogok, who extract very small gems. The material of intermediate fineness passes from the trommels to the pulsators, where it is separated more thoroughly again into heavy and light fractions. The heavy fractions are carefully sorted by hand three times, whereby the gems of any value are almost entirely removed. The machinery is largely driven by electricity, which is generated from a waterfall at the outlet of the valley. Besides these washing plants there are several sluices at work, which supply concentrates for the sorting sheds.

In addition to the rubies the *byon* contains large quantities of spinel, usually of a brilliant red colour, and more rarely sapphires and crystals of apatite. Black tourmaline is also common, but is of little value as a gem.

## Other Gemstones found in Ruby Mines Area.

(1) Apatite of a peculiar blue colour is found in Mogok.
(2) Chrysolite (peridot or olivine) of pale green colour is

said to occur in Bernardmyo and in Mogok. In the former locality it is apparently derived from the peridotitic rocks of the area.

(3) Chrysoberyl is rare, but is known to occur at and in the neighbourhood of Mogok.

(4) Moonstone is found east of Mogok.

(5) Garnet occurs very commonly in the Ruby Mines tract, but it appears to be sold in very small quantities by the local lapidaries.

(6) Iolite (cordierite or dichroite) or " water sapphire " is known to occur at Mogok, but is very scarce.

(7) Two varieties of lapiz lazuli occur at Mogok. The first variety has a deep indigo tint, the second is a white mass speckled with blue. The rock is composed of lazurite, haüyne, sodalite, and colourless minerals like white pyroxene, wollastonite, scapolite and calcite.

(8) Phenacite is of rare occurrence in Mogok.

(9) Epidote is also known to occur.

The output of rubies, sapphires and spinels during the years 1926–1930 is shown in Table on p. 5. In 1919 an exceptionally valuable ruby was found which was sold for three lakhs of rupees. The origin of the crystalline limestones in which the gems occur has been discussed in Chapter XI of *Geology of Burma.*

### Sagyin Hills, Mandalay District.

About 16 miles north of Mandalay a group of hills composed of crystalline limestones, which are largely quarried for statuary marble, rises abruptly from the alluvial plain on the left bank of the Irrawaddy. Sir Henry Hayden was the first to report on the locality. Moisture, acting along the joint planes of the rock, has produced fissures and hollows, which have been filled with the insoluble clayey material furnished by the disintegration of crystalline limestone containing spinel and ruby. This clayey material is recovered from the fissures and washed for sapphires, spinels and rubies. The best yield is obtained from clay of a yellowish colour. According to Captain Strove the rubies from this locality are lighter coloured and therefore less valuable than those of the Mogok neighbourhood. In recent years the workings do not appear to have been in a flourishing condition and no records of output are available.

### Nanyaseik Stone Tract, Myitkyina District.

The author had the opportunity of examining the stone tract of Nanyaseik in the Myitkyina district, where rubies were first discovered in the neighbourhood of the Kammo *Hka* north of Nanyaseik (25° 37′ 11″, 96° 35′) in the early nineties. Subsequently, the local inhabitants commenced prospecting in other areas. A notification was issued by the Government on the 28th June, 1894, to regulate extraction. The license fee was fixed at Rs. 20 per worker, and in the year 1896 there was a big rush, as the revenue received in that year was Rs. 49,245. During the next four years, 1897 to 1900, however, the revenue fell away largely, the amounts credited being Rs. 3,090, Rs. 1,500, Rs. 1,250 and Rs. 1,750 respectively. The 1896 boom lasted only for a year, and in 1897 the license fee was temporarily reduced to Rs. 10. In 1901 the discovery of another gem-bearing area south-west of Nanyaseik led to a rise in the revenue to Rs. 4,225. However, the discovery of the new field and the large influx of workers in 1901 led the local offices to raise the rate again to Rs. 20, which was responsible for the considerable decrease in the revenue collected from the mines.

Old Mining Centres.—The following are the old ruby mining centres:

**Marrawmaw.**—The old ruby mines lying between the Lahkraw *Hka* and the Marraw *Hka* are called by the Kachins *Marrawmaw*. The Lahkraw *Hka* is an important tributary of the Namya *chaung* and joins the latter about three-quarters of a mile south-south-west of the deserted village of Nanya (25° 37′ 20″, 96° 34′ 11″). There are numerous old shallow pits or open cuttings more than a few thousand in number along the stream banks. Their common depth and diameter is about three to four feet, but they have been partly filled with earth and overgrown with dense jungle. However, the maximum depth of a pit may be as much as about seven yards, though generally the depth varies from three to twelve feet.

The diameter of a big pit may be as much as ten feet. The general section seen in one of these ruby mines, in descending order, is as follows :

(3) Overburden : brownish, reddish or yellowish loam or alluvium at the top.

(2) Gem-bearing gravel or *byon*, one to four feet in thickness.

(1) Bed-rock or " phah " which is either granite or limestone. In the latter case the soil is very light and porous.

The author observed the following sections in two pits :

*A*. Overburden, loam, five feet six inches ; gem-bearing gravel or *byon*, one foot six inches.
Decomposed granite.
The water level was six feet four inches from the surface.

*B*. Overburden, loam, three feet ; gem-bearing gravel, two feet. Weathered lateritised granite.

The *byon* contains quartz, felspar, phlogopite, chlorite, calcite, spinel and ruby. The last two minerals seemed to be rather rare. It is interesting to note that the coarser the *byon* the bigger the rubies.

The author was informed that good rubies were comparatively more plentiful here than in other mining centres. When these mines are active Shan women wash for gold, as they do at present in the Jade Mines area, while their male relatives work for rubies and other gemstones. Numerous old workings are seen along the banks and the adjoining portions of a small stream locally called the Shayat *Hka*, issuing about half a mile north-east of the deserted village of Nawhkum (25° 39′ 2″, 96° 32′ 41″). A small outcrop of coarsely crystalline limestone in contact with granite is exposed in the stream. In another small stream, locally called the Kyan *Hka*, a tributary of the Kammo *Hka*, many old pits are to be seen in the beds, banks and vicinity of the stream. *Byon* here mostly consists of weathered granite detritus, derived from the contact of granite with limestone. In some places it is a bluish clay or loam on account of the decomposed felspar.

**Mawthit.**—On the west and south of the granite hill 804, marked on sheet 928/10, where it approaches the Kammo *Hka* the old ruby mines disappear, but reappear to the east of the above-mentioned hill. These old workings are called Mawthit.

It may be added that old workings are seen at intervals all along the left bank of the Kammo *Hka* and continue down to the Padau village (25° 37′ 54″, 96° 33′ 51″). The natives seem to have prospected in other places also, *e.g.* about four-fifths of a mile north of Padaw a few deep pits were seen away from the stream. Old workings (Mawgyi) are said to occur along the upper course of the Kammo *Hka* above the deserted village of Nawhkum. It must be noted that since these mining centres were deserted, now exactly 29 years ago, some confusion prevails about their nomenclature; in particular, the Kachins and Shans have separate names for the same mining centres.

Another locality where the Kachins washed for corundum in the bed of a little hill-stream in the past is situated in the hills west of the Indaw *chaung*, about four miles north of Manwe. A. W. G. Bleeck mentions another locality, 13 miles north-west of Nanyaseik, where deserted ruby pits are also reported. Bleeck examined the gravel taken from the dry bed of the first locality, and its constituent minerals proved to be quartz, felspar, phlogopite, chlorite, garnet, spinel and corundum. The last two minerals are fairly abundant, more especially so the spinel, a handful of which can be collected in a few minutes. It occurs in octahedral crystals, up to half an inch in diameter. The colours of the spinels vary with the pellucidity, from an almost opaque dark green to a bright translucent red. The latter variety of colour, however, is rare. The corundum is not so abundant as the spinel, and the colour of this stone is dull pink. One of the larger pieces found measured three-fourths of an inch in diameter.

The mining methods practised at the time of working are described below. A small pit is worked by two miners, but generally three people work together. One man digs the earth with a very crude pick, another carries the earth away, and the third, when the *byon* is reached, starts washing. Water in the pit is baled out with long bamboo cups, sometimes two being tied together. This is a very tedious and slow process, and pumping water with bamboo cylinders as used in the Jade Mines is recommended.

Washing is done on a flat bamboo basket about twenty inches in diameter. In the centre there is an area, ten inches square, the mesh of which is about one-tenth of an inch and is coarser than the rest. While panning, the bigger stones remain on the basket, the smaller ones pass through, and a constant eye is kept for small rubies in the material fallen below. Mayaws or water channels for a crude hydraulic sluicing of the overburden are also worked, especially during the rains.

## Origin of the Rubies and Spinels.

In the Nanyaseik district limestone is well exposed in a number of important outcrops, some of which show intrusive contacts with granite. Where this is the case the limestone has been converted into a handsome marble, often coarsely crystalline, with calcites up to one and a half inches or more in length. Locally the marble is rich in accessory minerals, though normally it has been bleached to a pure white. Of these accessories the most abundant as seen in hand specimens is graphite, though this disappears in the process of section making. Next in order of importance are forsterite, largely converted into a pale-coloured serpentine, prismatic crystals of phlogopite, rounded grains and occasional euhedrons of garnet near hessonite in composition, small red or pink spinels, grains of chondrodite and pyrrhotite, apatite and very rare, deep red rubies, showing their distinctive basal parting.

The author's discovery of fossils in these rocks proves the marbles to be contact-metamorphosed Anthracolithic Limestone. The mineral-assemblage, forsterite-spinel-garnet, is characteristic of the contact-metamorphism (or dedolomitisation) of impure dolomitic limestones. Obviously aluminous sediment and silica must both have been present in the original rock. The occurrence of abundant corundum in the marbles of Mogok has been explained by the possible metamorphism of associated limestones and bauxites (the last being free from silica), rather than limestones and normal clay rocks.[1]

[1] Rastall, R. H., *Physico-Chemical Geology*, 1927 (Arnold), p. 145.

Both chondrodite and phlogopite are fluosilicates, and their presence in the marbles bears witness to the introduction of fluorine from the granitic magma, while the pyrrhotite may be either a product of pneumatolysis, or of the alteration of original pyrites.

Admittedly the same mineral-assemblage has elsewhere resulted from the *regional* metamorphism of impure (argillaceous) dolomitic limestones; and in this connection reference may be made to the fact that high-grade metamorphism of this type results in the disappearance of aluminous silicates such as hornblende, in favour of non-aluminous forsterite, while the released alumina appears as spinel, in the presence of magnesia,[1] or, one may assume, as corundum in its absence. In the Nanyaseik area, however, the field evidence is strongly in favour of the claim that the gems are products of contact-metamorphism. Their irregular distribution in pockets is probably due to original differences in the composition of the sedimentary rocks which were invaded by the granites.

It remains to be seen how far this explanation is applicable to the other occurrences of gem-bearing marbles—for example, at the Sagyin Hills and Mogok.[2] In the Mogok Stone Tract most of the rubies come from the crystalline limestones or marbles referred to on page 8, and are commonly enclosed in calcite. In these cases there can be little doubt that the rubies have originated by contact-metamorphism of dolomitic limestones as is claimed for the gems in the Nanyaseik area; but all the corundum gems have not originated in this way, as sapphires occur in pegmatite veins and in curious felspar rocks that are evidently desilicated acid intrusives. These consist of felspar, dominantly albite, with apatite as the only other constituent, and pass marginally into nepheline-bearing rocks, some of which resemble the corundum-syenites of South India.[3]

[1] Harker, A., *Metamorphism*, 1932 (Methuen), pp. 256, 257.

[2] La Touche, T. D., "Geology of the Northern Shan States," *Mem. Geol. Surv. Ind.*, vol. xxxix, 1913, p. 42.

[3] Brown, J. Coggin, *Mining Mag.*, vol. xlviii, 1933, pp. 329-340.

## SAPPHIRE.

The blue and white varieties of sapphire are found commonly associated with the rubies in the crystalline limestones described above ; but sapphires are not associated with the rubies in the limestones at Mogok. The proportion of blue corundum found in the gem gravels is usually much smaller than that of the red variety, though the stones are often of larger size. It is significant that at the well-known mine at Kathe near Kyaungdwin there are thick veins of the felspar rocks mentioned above, consisting of albite-rich microperthite. The sapphires here are obtained from detrital deposits, and it may well be that the gems have been shed into the latter from the igneous veins.

## SPINEL.

Spinels are found in large quantities and in the same conditions at the localities described under " Ruby." In addition to the occurrences referred to above, Griesbach found large numbers of spinels in the sands of the Irrawaddy above Myitkyina, especially at the village of Watu (25° 30′, 97° 30′). They have also been reported to occur in quantity near the junction of the Pungin *Hka* and Mali *Hka* (25° 49′, 97° 32′), above the confluence.

## ROCK-CRYSTAL AND TOPAZ.

Both rock-crystal and topaz occur at Sakangyi, near the 42nd mile-post on the Thabeitkyin-Mogok road in the pegmatite veins in the gneiss. In 1922-23 some extraordinary large crystals of transparent quartz were found, some of these measuring four feet long by one foot wide. The rock-crystal, which finds a ready market in China, is sought after by Chinese traders. Topaz also occurs in large, but very pale yellow to colourless, transparent crystals. The pale colour, however, renders it practically useless as a gem.

## TOURMALINE.

Rubellite mines occur about a mile east of Maingnin (23° 14′, 96° 46′), surrounding the Palaung village of Sanka. The mines are said to have been discovered by Chinese some 150 to 200 years ago, but were deserted until 1869, when they were re-opened by some of the Kachin chiefs. E. S. George has written a history of the working of these mines. The matrix of the tourmaline is described as a vein of granite which has become decomposed through kaolinisation of the felspar, and is covered by a considerable thickness of red surface soil. The white vein, known locally as *kyaw*, is reached by vertical shafts or *twinlones*, four feet square and varying in depth from 60 to 75 feet, while the maximum depth is about 100 feet. Each owner is allowed to extend his workings along the vein to a distance of about 30 feet from the centre of the shaft. The "veins" are fairly deep down, none having ever been reached at a lesser depth than about 54 feet, while the average depth is 60 or 75 feet. Working in the *twinlones* ceases in the rains. All the material dug out from inside the *twinlon* is hauled up to the surface in small buckets, all raised by enormously long pivoted bamboos worked with a counterpoise. The tourmaline is sorted out by hand, the granite fragments being piled in a well around the mouth of the shaft. Attempts to reach the vein by hydraulic sluicing have not proved quite successful owing to the lack of water except in the rainy season.

The tourmaline is very irregularly distributed and a successful venture is a matter of pure speculation. The mineral varies in colour from brown or black to a light transparent pink, the latter being of course the most valuable variety. The gems are sold by weight; the pink variety known as *Ahtet yay* fetches from Rs. 1,200 to Rs. 1,500 per viss (3·65 lb.), while the inferior variety is sold for about a third of that price. No returns of output are available since 1909, when it amounted to 5·1 lbs., valued at £36. It is stated to be impossible to give an average time as to how long it takes to collect a viss, as finding the gems is so uncertain.

### Möng Lông, Northern Shan States.

The tourmaline-bearing gravels of Möng Lông form a river terrace situated higher up in the valley of the Nampai than the Ruby Gravel, and extend up to 200 ft. above the present level.

The workings are situated in the valley of the Nampai river, two or three miles to the north of the town of Möng Lông, in thick beds of gravel-like detritus washed down from the hill-slopes to the north of the valley. These hills are composed of gneiss, penetrated by broad veins of granite containing tourmaline as an accessory constituent. The gravels have been trenched in all directions in search of gems, a rude system of hydraulic sluicing being employed. Though black tourmaline is common, crystals of the red variety are said to be occasionally found. The output fluctuates considerably from year to year. In 1908, 32 stones valued at £289, and in 1909 seven stones valued at £26, were found, but since then no returns have been available.

### Ruby Mines, Mogok, Katha District.

Rubellite is found in the southern part of the Ruby Mines under the same conditions as in Möng Lông. During the four years 1904–7 an average output of 101 lbs. of the mineral per year was recorded, but no returns have been received in the subsequent years.

### Namôn, Karenni Hills.

At Namôn (19° 22′, 97° 35′), 13 miles to the north of Ywathit on the Salween river, crystals of a beautiful, dark green variety of tourmaline, varying from the size of a pea to that of a small bean, are found scattered through the surface soil, which is a brown sandy clay with pisolitic ferruginous concretions, and are mined on a small scale. The sandy material is taken out, sorted by hand and finally washed in the stream. The occurrence has been described by Middlemiss, who records that the matrix of the tourmaline is a white crystalline limestone, blocks of which are strewn over the hill-slopes where the pits are situated.

## ZIRCON.

*Both the flame-coloured zircon (hyacinth) and a blue zircon* are found at Mogok and in the neighbourhood, but the colourless zircon, which simulates diamond in lustre, does not seem to occur.

## BERYL.

According to Mason beryl occurs in the sands of the Irrawaddy, and this writer suggested that it might be found also in the streams descending from the hills to the east. Apparently no search has been made for these stones, but, however, aquamarine of a sea-green and bluish-green colour is found in granite-pegmatite at the Sakangyi mines, near the 42nd mile on the Thabeitkyin-Mogok road. It also occurs at Mogok.

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# CHAPTER III

## JADEITE.

THERE is little need to stress the interest and importance of jadeite. As a semi-precious stone of great beauty it has been known to man since very early times. It is greatly prized by the Chinese, with whom it is a sacred stone possessing certain magical properties, and by far the greater part of the total output of jadeite has eventually found its way to China; but as the full appreciation of its wonderful colouring and its decorative value came to be appreciated, the demand has increased in Western countries also. To the geologist jadeite offers many problems, chief among them being the conditions of its formation, and several divergent views have been expressed by those who have studied the mineral and its associates. On these grounds the author feels justified in giving jadeite rather full treatment, particularly as he has had the opportunity of studying the occurrences in the field and of examining the rocks and minerals of the jadeite area in the laboratory.

The history of the jadeite trade from very early times up to 1893 has been summarized by Mr. Marry of the Chinese Consular Service and was reprinted in the Myitkyina District Gazeteer compiled by W. A. Hertz in 1912.

The first geologist to visit the jadeite mines was F. Noetling, whose preliminary report on the economic resources of the Amber and Jade Mines area in Upper Burma was published in 1892.[1] The same author published an article on the occurrences of jadeite in Upper Burma and illustrated the account with a small-scale map. Professor Max Bauer described the rocks and minerals collected by Noetling.[2]

[1] *Rec. Geol. Surv. India*, vol. xxv, 1892, pp. 130-135.

[2] *Rec. Geol. Surv. India*, vol. xxvii, 1895, pp. 91-105.

But he was under the serious disadvantage of not having studied the field relationships of these rocks. A. W. G. Bleeck visited the area in 1907 [1] and reference to his work will be made in the sequel. Recently Professor Lacroix also has published an account of the jadeite rocks of this region.[2] The author commenced the systematic survey of the jadeite-bearing region in 1928 and a brief resumé of his conclusions has been published in the General Reports of the Geological Survey of India for the years 1928, 1929 and 1931.[3] A complete list of references published on the jadeite of Burma is appended at the end of this chapter.

**Area and Extent.**—The area so far known at present in which the mineral jadeite is found in Burma, is situated between 25° 28′ and 25° 52′ N. lat. and 96° 7′ and 96° 24′ E. long. The co-ordinates given above include the main, well-known area which supplies almost the entire output of jadeite obtained in Burma. However, there are other places where jadeite is known to exist: one locality lies about ten miles east of Mohnyin (24° 46′ 50″, 96° 22′ 30″) and another one occurs on the bank of the Chindwin river. Jadeite also exists at about 200 miles north of Myitkyina, but the place is inaccessible and the quality of the jadeite is reported to be poor.

The region is a highly dissected upland, consisting of ranges of hills which form the Chindwin-Irrawaddy watershed. It is higher in the north than in the south, and Tawmaw (25° 41′ 13″, 96° 15′ 18″), which is situated on the plateau, is 2,755 feet above the sea. The highest point in the area is Mount Loimye, 5,124 feet above sea-level.

The Uru [4] *chaung*, the main stream of the area, runs along the foot of the plateau from north-east to south-west. Not infrequently this river has cut deep gorges, often flanked by cliffs or sheer precipices several hundred feet high. The current is rather strong and during periods of flood carries away whatever comes

[1] *Rec. Geol. Surv. India*, vol. xxxvi, 1908.

[2] *Bull. Soc. Franc. Miner.*, vol. liii, 1930, pp. 216-254.

[3] *Rec. Geol. Surv. Ind.*, vol. lxii, 1929, pp. 55-57 and pp. 108-114 ; *Ibid.* vol. lxiii, 1930, pp. 38-42 and pp. 97-102 ; *Ibid.* vol. lxvi, 1932, pp. 62-63 and pp. 85-88.

[4] Marked Uyu on the map.

in its way, so much so that more than half the important and flourishing village of Hpakan (25° 36′ 38″, 96° 18′ 40″), the centre of the jadeite trade, was washed away in 1927. The Uru is an

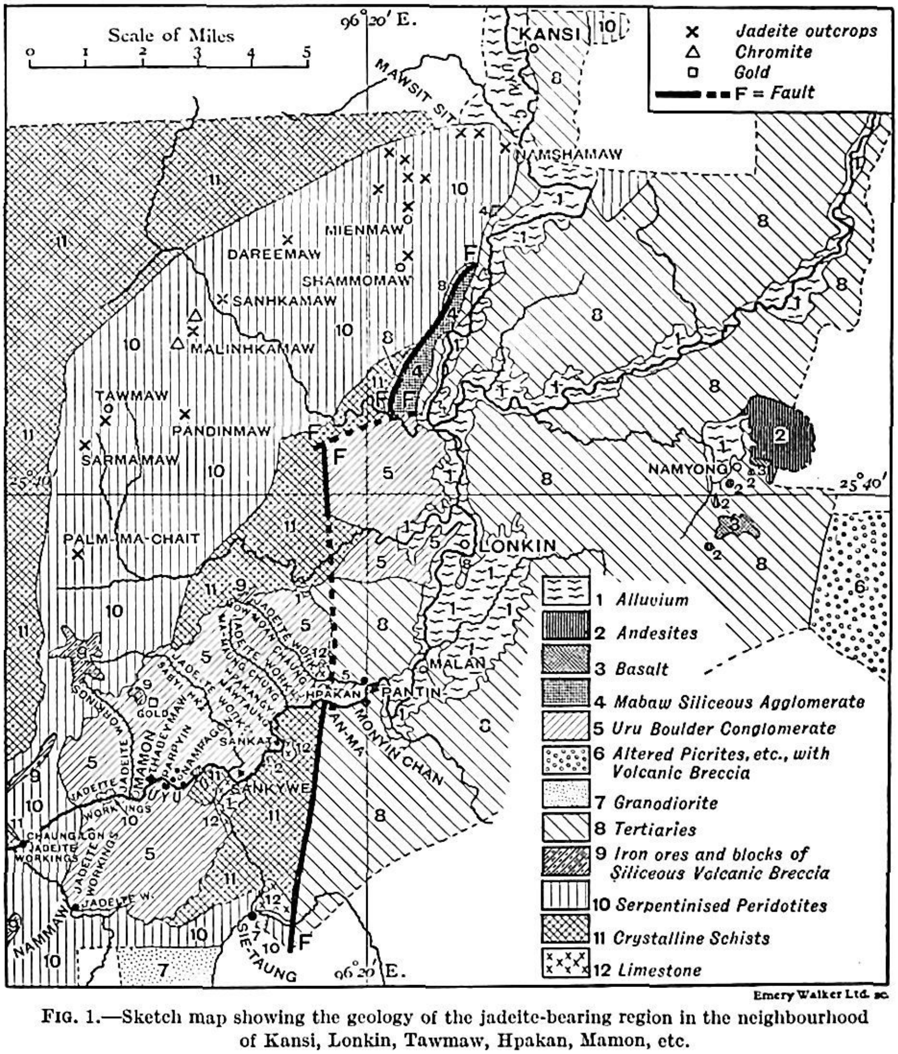


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FIG. 1.—Sketch map showing the geology of the jadeite-bearing region in the neighbourhood of Kansi, Lonkin, Tawmaw, Hpakan, Mamon, etc.

important degrading stream, and its banks and small feeders are the scene of much mining activity for jadeite.

Tawmaw, where the true outcrop jadeite mines are situated, is about 68 miles by road from Mogaung railway station, which lies on the Sagaing-Myitkyina branch of the Burma railways. From Mogaung to Nanyaseik (25° 37′ 6″, 96° 35′) there is an unmetalled motor road, but the portion between Kamaing (25° 31′ 38″, 96° 43′ 5″), the headquarters of the jadeite mines region, and Nanyaseik becomes very difficult after a few showers of rain. The tracks are flat for about another four miles from Nanyaseik, but beyond that there is only a well-graded, though locally very steep, mule-track passing over a range of hills.

## GEOLOGY OF THE AREA.

There are serious difficulties in the way of detailed geological mapping: survey work is impeded by the almost impenetrable jungle, which in places is so thick that it is possible to see only a few feet ahead. Further, it is a particularly unhealthy region and the jungle is infested with insect pests.

Within the area much of the surface is occupied by Tertiary rocks (see Fig. 1), to the west of which lies a great intrusive complex consisting essentially of serpentinised peridotites, the outcrop being elongated north-east to south-west and being roughly oval in shape. This complex is surrounded by crystalline schists which include types derived from both sedimentary and igneous rocks. The former appear to represent the country-rock into which the plutonic complex was injected. The Uru Boulder Conglomerate of Pleistocene to Sub-Recent date occupies a considerable area north-eastwards from Nammaw, and is important on account of its jadeite workings. A brief account of each of the formations occurring in the Jade Mines area is included in this chapter. The succession is summarised in tabular form below:

| | | |
|---|---|---|
| XIII. | Alluvium - - - - | Recent. |
| XII. | Uru Boulder Conglomerate - | Pleistocene—Sub-Recent. |
| XI. | Volcanic Rocks - - - | Late Tertiary—Recent. |
| X. | Granodiorite - - - | Late Tertiary. |
| IX. | Gabbro - - - - | Late Tertiary. |
| VIII. | Namting Series - - - | Mio-Pliocene. |
| VII. | Hkuma Series - - - | Oligo-Miocene. |
| VI. | Highly altered picrites and volcanic breccias - - | Early Tertiary age. |
| V. | Jadeite-albite rocks - - | Early Tertiary age. |

| | | |
|---|---|---|
| IV. | Granites - - - - | Late Cretaceous—early Eocene. |
| III. | Serpentinised peridotites - | Late Cretaceous—early Eocene. |
| II. | Crystalline schists - - | Partly of unknown age and partly of early Tertiary age. |
| I. | Limestone - - - - | Palaeozoic, possibly Permo-Carboniferous. |

### The Plateau Limestone.

Small outcrops of limestone are common and their characters have been described in the author's *Geology of Burma,* 1934, p. 175. The limestone is generally crystalline, approaching marble, where it has been invaded by igneous intrusions. It is well jointed and occasionally it is highly brecciated.

The ordinary limestone, under the microscope, consists of calcite, forming irregular mosaics in places, set in a dusky, opaque material, which under high power resolves itself into extremely fine grained calcareous matter. A network of veins of calcite traverses the rock in all directions. The limestones yielded the remains of *Fenestella* and of foraminifera, including *Fusulina elongata*, *Textularia* and various forms of *Globigerinidae.* Minute circular and rod-like sections of *rhabdoliths* and *coccoliths* respectively are frequently observed under the microscope.

About one furlong west-south-west of the confluence of the Hwehka and Nammon *chaungs,* the limestone near its contact with serpentinised peridotites has undergone metasomatic replacement. Macroscopically it appears like a black chert, breaking with conchoidal fracture, and is seen to consist of an extremely fine mosaic of silica, the fossils also being replaced by this material. Perfect rhombohedral crystals of dolomite have undoubtedly resulted from the contact metamorphic effects of the serpentine intrusion.

### Crystalline Schists.

Under the name of " Crystalline Schists " is here included the dual complex of basic igneous rocks, ranging from diorites and gabbros to pyroxenites and peridotites, and true schists. The latter are evidently older that the serpentinised peridotites and other igneous rocks of the area and form the basement upon which the subsequent formations were deposited. The ortho- and the para-schists in places are so intermingled that it is impossible to separate them on the present one-inch maps. The ortho-schists encircle the peridotites and serpentines and are most probably the result of differentiation of the same magma. The prevailing type is epidiorite, especially striking when it contains white circular phenocrysts of saussuritised plagioclase : originally this rock must have been a gabbro. Other types which are quite common in the area include glaucophane-, hornblende-, chlorite-, kyanite-, quartz- and idocrase-schists. It may be noted that idocrase is a common constituent of the schists, especially of those collected near the limestones. Injections of pegmatite and aplite also occur in these rocks. The epidiorite proves to consist of rounded phenocrysts of saussurite embedded in a matrix of soda amphibole and actinolite. In places the amphiboles have been altered to chlorite. Inclusions of iron ores are present. The circular phenocrysts of felspar (saussurite) contain clusters of inclusions of amphiboles, zircon and iron ores. Some clear, secondary quartz is also present.

A rock obtained from the bed of the Sanhka *chaung*, about $2\frac{3}{4}$ miles north-east of Tawmaw (25° 41′ 13″, 96° 15′ 28″), contains, in addition to amphiboles and felspar (saussurite), colourless augite, garnet, zircon and zoisite. The augite is colourless and clear with an extinction angle of 48°, and shows simple twinning. The garnet is colourless and occurs either in dodecahedral or circular sections. Some secondary quartz is also present. Irregular aggregates of chromite are scattered all through the rock.

**Graphite-schists.**—Graphite-schists are fairly common in the area. It is not improbable that the epidiorites, described above, in places have been altered into these schists. They are greyish black in colour, sometimes with conspicuous reddish-brown pseudomorphs, which appear like garnets at first sight. With a pocket-lens graphite, quartz and some ferruginous material can be seen.

Thin sections consist of a schistose aggregate of quartz, graphite, with some mica and felspar. The phenocrysts are represented simply by circular, clear patches of quartz, which in places are veined by limonite. It appears either that the felspar phenocrysts of the epidiorites, described above, have been replaced by limonite and quartz; or these pseudomorphs may be after garnet. Most of the quartz present in the rock appears to be secondary. It seems that along with dynamic stresses, hydrothermal waters containing silica, iron ores, etc., and *carbon* played their part in forming these schists. In places the minerals have been arranged in parallel folia but the latter have sometimes been bent and thrown into acute folds.

**Quartz-schist.**—Macroscopically, the quartz-schists are whitish, finely foliated schists which consist of quartz and felspar with reddish-brown streaks due to iron staining. Under the microscope a mosaic of the same two minerals is seen with a yellowish or yellowish-brown amorphous mineral, which in places assumes a reddish-brown colour on account of iron staining. Small lozenge-shaped, circular or needle-shaped crystals of sphene are also present.

**Kyanite-schist.**—Kyanite-schists were collected from one-third of a mile south-east of Saingmaw (25° 35′ 0″, 96° 17′ 30″), in the stream of the same name. They consist of glistening bright-green blades of kyanite set in a talcose matrix. In places sheaf-like aggregates are to be seen and the blades are often bent. Talc, it appears, has been formed partly by the alteration of kyanite, a fact confirmed by the microscope. The presence of kyanite indicates that the rock, presumably a sediment originally, has been subjected to high-grade dynamo-metamorphism.

**Glaucophane-schist.**—Glaucophane-schists are quite common in the area, and are greyish-blue rocks which, under the microscope, are seen to consist of glaucophane with some muscovite set in a granular mosaic of quartz. Generally the glaucophane occurs in prismatic sections, in places with conical terminations. The normal prismatic cleavage occurs along with transverse cracks. It shows the characteristic pleochroism: X, pale yellow to very light brown; Y, violet or light purple; Z, Prussian blue. The birefringence is weak. It appears that the mineral is an abnormal glaucophane,[1] since the sections containing the X-axis show rather wide extinction angles, the

[1] See Winchell, *Elements of Optical Mineralogy*, 1927, vol. ii, p. 209.

maximum being 22·5°, and the birefringence is stronger too in this case. In view of the presence of jadeite-bearing rocks in the neighbourhood, these glaucophane-schists are significant, as glaucophane contains the jadeite molecule.

**Chlorite-schists.**—The chlorite-schist from a little west-southwest of the Rest House of Mamon consists of greenish, ragged aggregates of chlorite formed as a result of the alteration of hornblende. The former shows its usual characteristics. Aggregates of colourless, granular augite are scattered throughout the rock. Associated with the chlorite are lenticles or irregular aggregates of saussurite in which numerous fine needles of amphibole occur as inclusions. A few irregular blebs of sphene and leucoxene are also present. The rock is evidently a normal 'green schist' formed at the expense of a basic igneous rock.

**Vesuvianite-schist.**—This rock proves very interesting under the microscope. It is seen to consist of prismatic, pyramidal and subangular sections of vesuvianite (idocrase) with imperfect prismatic cleavage and transverse cracks. Although most sections show normal characters, in places, however, apparently the same mineral shows ultra-blue polarisation colours and a maximum extinction angle of 21° measured on the prismatic cleavage. This probably represents the variety of vesuvianite recorded by Dana. The oblique extinction is most probably due to the great dynamic stress the rock has undergone. It is embedded in a schistose aggregate of quartz and felspar. Light green chlorite in thin flakes is also present.

A coarser textured specimen from near the junction of the schists and serpentines is similar, but contains more chlorite and felspar and is stained with limonite. Occasional sections of glaucophane are also present. Brownish haematite after magnetite also occurs.

**Spotted actinolite-zoisite-schist with pegmatitic injections.** A specimen, collected from the Nangma *hka* just a little south of "h" of *hka* (92 C/6), consists of granular aggregates of actinolite, zoisite, epidote, and vesuvianite with a little augite, quartz and felspar. The felspar occurs in circular sections containing numerous inclusions of acicular actinolite. Of these minerals, zoisite is the most interesting and forms a fair proportion of the rock.

The schist is injected by fine pegmatites consisting of quartz and muscovite.

Another similar rock from the Sanhka *hka*, less than half a mile west of "897," contains muscovite in addition to the minerals described above.

**Mica-pegmatite.**—Mica-pegmatites were observed in the Sanhka *chaung*, about 2¼ miles S.W. of Kansi (25° 47′ 1″, 96° 22′ 48″). They consist of a granitoid aggregate of quartz, felspar and muscovite, the last mineral occurring in elongated blades. It is also present as inclusions in felspar, and in places the felspar and muscovite form a micrographic intergrowth and enclose sections of quartz. Thin aplitic veins consisting of a fine granular mosaic of quartz and felspar with a little mica are seen traversing the rock. Prismatic sections and irregular blebs of colourless vesuvianite also occur.

**Hornblende-peridotite.**—Specimens of a very interesting rock were obtained from the first stream, *en route* to Sietaung, about half a mile north-east of "1316" hill marked on the map (sheet 92 C/6). Macroscopically the rock is a beautiful aggregate of glistening black crystals of hornblende and pale green olivine. Small crystals of a reddish-brown mineral are also visible. A thin section consists almost entirely of bluish-green hornblende (smaragdite) with some clear olivine, diopside, and greenish augite. Titanite or rutile also occurs both in rounded and prismatic sections. The rock is actually a hornblende-peridotite near to hornblendite of Dana. A similar rock was discovered as an ejected block from the Twindaung crater in the Lower Chindwin region.[1]

**Granite-gneiss.**—A coarse porphyritic granite-gneiss, which is interbedded with the crystalline schists, is seen in the Sage *hka*, a stream which joins the Hkara *hka* about one furlong from the latter's confluence with the Tanai *hka* on one-inch Survey of India Sheet 92 C/13. The gneiss shows a texture varying from that of a fine grained schistose rock to that of a coarse granite-gneiss. In the Tanai *hka*, near its confluence with the Hkara *hka*, it assumes the aspect of a micaceous schist, being very finely bedded and dipping north-east at high angles. It is also highly jointed and cleaved into small pieces, moreover,

[1] *Trans. Min. Geol. Inst. Ind.*, vol. xxi, 1927, p. 216.

the dip is vertical, the rock is very crumpled and shows evidence of minor strike-faulting.

### Serpentinised Peridotites.

An extensive complex of peridotites, which in places have been partially or wholly altered to serpentine, extends southwards from the Sanhka *hka* (on the one-inch sheet 92 C/5) and a tributary of the Namsai *hka* to the latitude of Haungpa (25° 30′ 48″, 90° 6′ 15″). A. W. G. Bleeck depicted it as two separate outcrops ; but it is really one continuous mass as seen in the Uru *chaung* below Mamon (25° 35′ 10″, 96° 15′ 57″). Another outcrop on the one-inch sheet forms the hills " 1448 " and " 1660," while another mass, slightly east-north-east of Kansi, forms hill " 2162 " (one-inch sheet 92 C/5). It is overlain by the Tertiaries to a height of about 1,200 feet and the remaining part of the hill is composed of serpentine which is highly brecciated in places. South and east of Hwehka, serpentine again outcrops, and must be connected underground with the main mass, but crystalline schists intervene for a little over one and a half miles west of Kadonyat (25° 3′ 20,″ 96° 15′ 46″).

A thick mantle of red soil covers the rocks, the ferruginous content of which has been concentrated in places to form iron ores. The peridotites include several different types, the most important being dunite-, mica-, hornblende- and diallage-peridotites, in addition to diallage-perknite (pyroxenite) and amphibolite. The serpentised dunite from Tawmaw with a density of 2·795–2·802 on analysis by M. Raoult yielded the following results :

| | |
|---|---|
| $SiO_2$ | 34·34 |
| $Al_2O_3$ | 0·37 |
| $Fe_2O_3$ | 3·60 |
| $FeO$ | 7·04 |
| $MnO$ | 0·15 |
| $MgO$ | 42·58 |
| $CaO$ | 0·54 |
| $Na_2O$ | 0·41 |
| $K_2O$ | 0·17 |
| $TiO_2$ | — |
| $P_2O_5$ | tr. |
| $H_2O+$ | 10·12 |
| $H_2O-$ | 0·31 |
| $Cr_2O_3$ | 0·49 |
| | 100·12 |

## Granites.

In the Myitkyina district[1] of the Jade Mines area granite occupies a wide expanse of country, forming thickly forested hills up to 1,500 ft. in height, and scattered knolls. The wide extent of the granite suggests that it has the form of a batholith, and it may be regarded as complementary to the ultrabasic complex described above, and of approximately the same date. In the main the rock is a medium-grained pink or grey granite, a type containing biotite being dominant. In addition to this, however, two-mica granite, hornblende-granite and micro-granite, as well as more basic types, including monzonites, are well represented, while dioritic xenoliths in the acid rocks may well be interpreted as digested fragments of even more basic, early types.

In texture the granite varies from the normal xenomorphic granular to graphic and micrographic, and there is frequently a slight foliation to be seen, impressed on the rock during the consolidation of the magma. Magmatic residua are represented by pegmatites and aplites, while the final product of consolidation was quartz which frequently veins the granite.

These rocks are of special significance in connection with the problem of the origin of the unique jadeite-albite rocks, considered in detail below.

## Altered Picrites and Volcanic Breccias.

Locally volcanic rocks, associated with highly altered picrites, occur, and perhaps represent the extrusive phase of the same igneous cycle which gave rise to the ultrabasic and acid complexes described above. As they are of no significance in connection with the genesis and exploitation of the jadeite-bearing rocks, it is not necessary to describe them fully, and only notes on some of the more interesting occurrences are included in this account.

The picrites are represented often by rocks exceedingly rich in epidote, so much so that the term " epidosite " seems the most appropriate name to apply to them. In addition to the abundant epidote, haematite and limonite also occur and are

[1] *Rec. Geol. Surv. Ind.*, vol. xliv, 1930, p. 98.

generally seen filling up the central portions of the felspars. Serpentine with some chlorite also occurs in ragged or irregular patches.

These epidosites bear a striking resemblance to similar rocks from Punta Parate, Ajaccio, Corsica, and also to those from the Lizard, Cornwall, England. Originally they must have been very basic rocks, probably picrites, but the ferromagnesian mineral, mostly pyroxene, which is still seen in residual patches in some slides, and felspar have been changed by metamorphism to epidote.

**Altered andesite-tuff.**—A light-grey rock which reveals its clastic character under close observation is commonly associated with the epidosites described above. Under the microscope it is seen to be composed of fragments of volcanic, particularly andesitic, rocks. The latter contain large prismatic and octagonal phenocrysts of augite and prismatic felspars set in a fine grained groundmass containing magnetite crystals. The felspar in some cases is rendered opaque, while in others it is altered to a mosaic of secondary felspar and sericite. Some rock-fragments in the tuff consist of aggregates of fine lath-shaped felspars, with some augite, while others are altered almost entirely to greenish serpentine with grains of magnetite. Some are dark and almost opaque.

In addition to several different kinds of andesite (of which augite-andesite is the chief), fragments of dolerite, serpentine, and palagonite with small globulites also occur. Since the fragments of andesite predominate, the rock is an andesite-tuff. Similar rock occurs just beyond the eighteenth mile on the Kamaing-Tawmaw road and just east of the stream.

**Serpentine tuffs.**—Serpentine-tuff, derived from basic rocks, was collected from the first S.W. bend before the nineteenth mile on the Kamaing-Tawmaw road.

In some of these tuffs epidote is present in abundance and angular fragments of the epidosites described above have also taken part in their constitution.

**Quartz-hornblende-dolerite.**—A small outcrop of intrusive dolerite was observed about two-fifths of a mile N.W. of the twenty-first mile on the Tawmaw–Kamaing road. The rock is dark grey in colour, of medium texture and weathers by exfoliation. The specific gravity is 2·70. The constituents seen under the microscope are felspar, primary hornblende, uralite, quartz, apatite and magnetite with a little limonite. The felspar forms columnar and tabular crystals with inclusions of hornblende. In places it forms an almost homogeneous base in which long thin laths of labradorite are crowded together almost to the exclusion of other minerals. Green hornblende occurs both in idiomorphic and hypidiomorphic sections, but some portion of it is uralitised, while in places residual augite is seen associated with it. Quartz is interstitial, and apatite, in the form of needles, and magnetite occur as accessories. The texture is subophitic. The rock appears to be undoubtedly a basaltic dolerite; its porphyritic character is noticeable.

**Siliceous injections.**—These rocks have been injected with siliceous veins, *e.g.* near the stream, before the twentieth mile on the Kamaing–Tawmaw road. The rock is compact, slightly greenish in colour and under the microscope it is seen to consist of an extremely fine mosaic of quartz, felspar, sericite with a considerable proportion of opaque material which appears whitish by reflected light, and may be altered felspar.

## The Tertiary Rocks.

The author has classified the Tertiaries of this region as follows:

(2) Namting Series - - Mio-Pliocene.
(1) Hkuma Series - - Oligo-Miocene.

### *The Hkuma Series.*

Good sections of the Hkuma Series are exposed along the Shadu, Tagam, Hkuma and Hkada streams, of sheet 92 C/13, but since they were first met in the Hkuma *hka* and also form the high hill, 4,982 ft. above sea-level, known as Hkuma Bum, the author has designated them the Hkuma Series. In the Shadu *hka*, almost from its source to its confluence with the Sumpra *hka* they show a northerly dip which, however, fluctuates between north-west and north-east, at an average of 45°. Sandstones with occasional interbedded layers of shale or argillaceous sandstone are predominant. In places they are finely laminated, while in others they are coarse and pebbly.

The most striking feature is their extremely well-bedded character. They are greyish, greenish, whitish, pale-yellow or reddish in colour, sometimes with black carbonaceous streaks. In the Shadu *hka* alone, about 10,000 feet of these sandstones are exposed. In the Tagam *hka* sandstones are interbedded in places with black carbonaceous shales, which are sometimes very friable. Both sandstones and shales contain well-preserved fossil leaves ; those from the neighbourhood of Hwehka include *Tetranthera hwekonsis*. The shales are generally of a greyish colour and thin sections show dark-brown carbonaceous matter together with a considerable amount of calcite, some quartz and a little mica. A number of foraminifera belonging to the family *Globigerinidae* were observed in the shales from Hwehka (25° 29′ 3″, 96° 16′ 43″), and this tends to prove that a small inlet of the deep sea existed in the neighbourhood. This must have undergone very rapid changes as is shown by the interbedding of conglomerate, containing boulders of jadeite, various types of serpentine, peridotite, amphibolite, and hornblende-, graphite-, mica- and quartz-schists, proving that these rocks were exposed when the Tertiary sediments were being deposited. Bands of finely jointed, black, carbonaceous limestone also occur. The occurrence of coal and lignite is noteworthy.

On sheet 92 C/13 their junction with the crystalline schists and serpentines is faulted, as is shown in the Hkuma and the Hshamshing *hkas*. Similar rocks are also met with in the upper course of the Namjan *hka*, on sheet 92 C/5, and the upper portion of 92 C/6. They are the freshwater equivalents of the Pegu Series met with farther south, but it is possible that their base touches the Upper Eocene, as the heavy-mineral assemblages of some of the specimens correspond with those of the Barail Series (Eocene-Oligocene), of Assam.

### *Namting Series.*

Since the Upper Tertiary rocks containing fossil wood were first met with near Namting (25° 38′, 96° 27′), they have been called the Namting Series.[1] The type area lies between Namting and Lonkin (25° 39′, 96° 22′) which are eight miles apart. Their thickness must be considerable, since in places the strata

[1] *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, p. 88.

are vertical. They consist of sandstones, shales and conglomerates. The sandstones are of various colours, coarse to medium in grain size and sometimes pebbly. They contain many minerals, but quartz and felspar (both orthoclose and plagioclase), are predominant. Grains of epidote, glauconite, chlorite and serpentine are quite common; while muscovite, biotite, haematite, chromite and calcite also occur. Small grains of graphite and of graphite-schist are also present, while grains of jadeite prove that the intrusion of the jadeite-bearing rocks must have preceded the deposition of these rocks. Some of the sandstones are calcareous, but the majority are argillaceous. Small trunks of silicified dicotyledonous fossil wood were seen about a mile west of Namting, and small stumps of fossil trees, comprising both palms and dicotyledons, were found a little south-east of Namyong (25° 40′, 96° 26′). The inner portion of some is carbonised, but the outer is silicified.

Similar rocks are exposed in the Tarong *hka* near Tarongyang (25° 40′, 96° 45′), and the Tertiary rocks forming the low hills near Nanyaseik (25° 37′, 96° 35′) also belong to this series which is the equivalent of the Irrawaddy Series described in Chapter XXIV of the companion volume.[1] Specimens collected from them yielded heavy minerals, which, with a very few exceptions, agree closely with those from the Tipam Series of Assam.[2]

### The late-Tertiary Plutonic Rocks.

**Gabbro.**—Gabbro first appears about one and three-quarter miles west-south-west of △ 5124; in the Namjan *hka* which has cut a gorge with steep cliffs as far as its junction with the Loimye *hka*. From the latter point the rock ascends and is exposed at about 750 feet above the level of the stream and is overlain by the volcanic deposits of Mount Loimye. A little over half a mile north of △ 5124 it again makes its appearance and forms the " 4842," Bum-i-Bum, and " 4858 " hills, whence it extends northwards as far as the headwaters of the Namjan *hka* where the latter bifurcates into the Dab-Bum and the Chinkichu *hkas*. The gabbro is intrusive into the Tertiaries; in places *lit-par-lit* injection is seen, and xenoliths of the latter occur in the former. It is very finely banded locally, and towards

[1] *The Geology of Burma*, Macmillan, 1934, pp. 250-258.
[2] P. Evans, in *Rec. Geol. Surv. Ind.* vol. lxvi, 1932, p. 88.

its western boundary easterly dips ranging from 30°–50° are observed. Similar banding has been recorded in the case of the Tertiary gabbro of Skye.[1] East of the Namjan *hka*, north of its confluence with the Loimye *hka* for about 2 miles the gabbro comes into contact with greenish black basaltic tuff and, as a result of the intrusion, the latter has been baked, hardened, bleached and metamorphosed. Very probably this marks the position of one of the older vents which served as passages for the uprise of the basic eruptive rocks.

The form of intrusion near the eastern margin appears to be a concordant, inclined, composite sill or sheet.

The rock is generally of a greyish colour mottled with ferromagnesian minerals and shows considerable variation in texture. In places it is so fine-grained and granulitic that, without the aid of a microscope, it is difficult to distinguish it externally from basalt. However, coarse, massive gabbros are most common. The different modifications are described below :

**Massive, Coarse Gabbro.**—In the massive, coarse-grained gabbro the individual crystals of augite measure over 5 mm. in places. The specific gravity is 2·858. The thin section consists of a very coarse-grained aggregate of altered felspar and augite. The augite has altered, first to serpentine, which has further altered to a brownish opaque material with lacunae of chalcedony. Quartz and iron ores are also present.

**Microgabbro (Porphyritic).**—The rocks from the periphery of the sheet, represented by specimens collected from the left bank, just before the Namjan *hka* bifurcates into the Dab-Bum and the Chinkichu *hkas*, is finer-grained in texture. Under the microscope it is seen to consist of a fine-grained aggregate of felspar, augite and hornblende with a fairly large quantity of iron ores (magnetite and ilmenite) which make the rock look more basic than the one described above. Felspar is seen in places to occur in comparatively large phenocrysts. The specific gravity is 2·86.

**Quartz-augite-enstatite gabbro.**—Another variety is coarser in grain size, is greyish in colour, mottled black with pyroxenes. The specific gravity is 2·89.

Thin sections of this type consist of a xenomorphic-granular

[1] *Q.J.G.S.* vol. 50, 1894, p. 645.

aggregate of labradorite felspar and pyroxene, the texture being sometimes ophitic. The pyroxenes include both diopside and enstatite, but the former is predominant and in places a micrographic intergrowth of the two is seen. The enstatite appears to be ferriferous since in places it is slightly pleochroic. The pyroxenes have altered to both fibrous hornblende and serpentine. Some interstitial quartz is also present. Magnetite occurs in large hypidiomorphic patches. A little green mica, partly chloritised, is also present.

**Micrographic Gabbro.**—The rock collected from the Namjan *hka*, about a quarter of a mile south-east of its confluence with the Loimye *hka*, is greenish white in colour, and is composed of elongated crystals of felspar and augite, some of which measure over 10 mm. in length, though their breadth is not much over 2–3 mm.

In thin section this type is seen to consist of much elongated prismatic sections of felspar and diallagic augite, the former interpenetrating at various angles, forming sometimes star-and-cross-shaped aggregates. The interest lies in the groundmass which consists of a fine micrographic intergrowth of quartz and felspar; but not infrequently two felspars appear to be intergrown, though it is very difficult to ascertain their specific characters. Iron ores as usual are present. The rock seems to be an acidic alkaline gabbro and its chemical analysis [1] is tabulated below:

| | Graphic gabbro. |
|---|---|
| $SiO_2$ | 60·38 |
| $Al_2O_3$ | 13·75 |
| $Fe_2O_3$ | 5·33 |
| $FeO$ | 3·54 |
| $MgO$ | 1·17 |
| $CaO$ | 5·23 |
| $K_2O$ | 2·29 |
| $Na_2O$ | 4·09 |
| $H_2O+$ | 2·15 |
| $H_2O-$ | 1·03 |
| $CO_2$ | 0·02 |
| $TiO_2$ | 0·68 |
| $P_2O_5$ | 0·18 |
| $MnO$ | 0·20 |
| $BaO$ | 0·03 |
| | 100·07 |

[1] Analysis by T. Marrack, M.Sc., A.R.S.M.

**Granodiorite.**—Three outcrops of granodiorite have been mapped by the author.[1] The biggest has an extension of three and a half miles in a north-south direction as seen on the Saingmaw–Hwehka road. It is intrusive into serpentine in the north and into the Tertiaries in the south. Another occurs west of Mawkalon (25° 29′ 55″, 96° 18′ 4″). Its breadth is about half a mile and it extends to a little north of the deserted village of Namlan (25° 28′ 20″, 98° 18′ 51″). Very probably it is continuous with the granodiorite observed a little south of Sietaung, about two miles south-east of Saingmaw (25° 35′ 0″, 96° 17′ 30″). This also is intrusive into the serpentine, which, near the contact, has been rendered schistose. It touches the Tertiaries also in the Hwehka *chaung*, about three-quarters of a mile south-east of Mawkalon (25° 29′ 55″, 96° 18′ 4″) and these have been baked, hardened and are almost vertical near the contact. The third outcrop lies in the Mikilin *chaung* with boulders of breccia of the same rock lying on its surface.

Macroscopically the granodiorite is medium grey in colour, coarse grained and porphyritic in texture. The bulk of the rock is composed of felspars with some quartz and altered hornblende. The felspars comprise orthoclase, andesine and microcline, and have undergone both kaolinisation and sericitisation. Hornblende is brownish in colour and has changed almost wholly into green chlorite, though unaltered cores are occasionally seen. Magnetite occurs as an accessory mineral. Epidote is very commonly developed at the contact with serpentine.

**Quartz-diorite.**—The most common type has been described above, but basic varieties also occur, *e.g.* a little north of the confluence of the Nammon and Hwehka *chaungs*. They consist of pink felspars, dominantly plagioclase, and black, glistening hornblende with patches of dark fine-textured amphibole and felspar. Quartz is visible in thin sections but is very subordinate, and the rock appears to be a quartz-diorite. The felspar is very largely altered but, however, plagioclase is predominant.

**Camptonite.**—Fine-grained basic secretions occur and consist of clear laths of felspar with abundant idiomorphic crystals of hornblende, showing bluish green to brownish pleochroism and remarkable zoning. The two minerals seem to have crystallised

[1] *Rec. Geol. Surv. Ind.* vol. lxii, 1929, p. 111.

almost simultaneously. A fair quantity of magnetite is also present. The rock appears to be a basic modification of diorite and may be designated hornblende-camptonite.

**Quartz-porphyry.**—Small intrusions and injections of quartz-porphyry occur: (1) in the Saingmaw *chaung* about one and a quarter miles south-east of Saingmaw (25° 35′ 0″, 96° 17′ 30″); (2) on the Saingmaw–Hwehka road, about a mile east-north-east of hill 1879; and (3) in the Kadonyat *chaung* about half a mile west-south-west of Hwehka (25° 28′ 32″, 96° 16′ 43″). Specimens from the first locality show phenocrysts of quartz and felspar with irregular patches of amphibole and chlorite, but the interest lies in the groundmass which is composed of fully or partially developed spherulites embedded in an extremely fine mosaic of quartz and felspar. It is noteworthy that all these intrusions are soda quartz-porphyry and the rock from the last locality, mentioned above approaches keratophyre. A syenite-porphyry, intrusive into serpentine occurs near the deserted village of Sabyl (25° 37′ 27″, 96° 16′ 15″) (92 C/6).

**Genetic Relationships.**—There seems little doubt that there is a genetic relationship between the granodiorite, quartz-porphyry, quartz veins, rhyolite and rhyolite-breccia of this region. All these are of the same age and undoubtedly represent the intrusive, dyke and extrusive phases of the same cycle of igneous activity.

The volcanic rocks of this region have been described in the chapters on Igneous Activity, chiefly in XXVII, XXIX and XXXII in the companion volume.

### The Uru Boulder Conglomerate.

The Plateau Gravels of Upper Burma are represented in the north of the Myitkyina district by a boulder conglomerate, named by the author the Uru Boulder Conglomerate, after the river which was responsible for its formation.

The outcrop of the conglomerate attains to a maximum width of over four miles in the longitude of Mamon, which was formerly very famous for its jadeite workings, and thence it extends to the north and north-east as a belt with an average width of two miles on the right bank of the river. The thickness of the formation must exceed a thousand feet in places, as is evident from a traverse along any of the tributaries of the Uru, for example, the Sabyi or Mamon *chaungs*. In the case of the latter there is an abrupt descent from Balahka (25° 37′ 30″, 96° 17′ 1″), which is situated on the conglomerate at a little over 2000 ft. O.D., to the valley of the Mamon (Mamaung) *chaung*. The cliffs overlooking the stream are composed entirely of the conglomerate, and no other rock is seen until Hpākān (25° 36′ 38″, 96° 18′ 40″) is reached, near the 806 spot-level on the map, sheet 92 C/6, where crystalline schists are encountered.

The age of the conglomerate is probably Pleistocene to sub-Recent.

The Uru Boulder Conglomerate is strikingly polygenetic, and the older rocks of the neighbourhood are represented by boulders ranging in size from a few inches to several feet. They comprise several varieties of crystalline schists, including mica-, quartz-, glaucophane- and anthophyllite-schists; plutonic rocks of which the chief are granodiorite, diorite and epidiorite; metallic ores including limonite, haematite and chromite; and, most important from the present point of view, boulders of jadeite, for which the formation is worked. It is locally believed that the jadeite of the boulders in the conglomerate is more "mature" than that of Tawmaw. The obvious difference between the two types is due to the removal, during transport, of the skin of weathered mineral in the former case.

Sometimes beds or lenticles of sand-rock occur intercalated in the conglomerate and a specimen hammered from about half a mile west-north-west of Mamon (25° 35′ 10″, 96° 15′ 57″) contains the following minerals along with fragments of quartz- and other schists; quartz, serpentine, chlorite, garnet, hornblende, muscovite, saussurite, etc.

## JADEITE-ALBITE ROCKS.

The alignment of the known jadeite outcrops suggests that there are at least four jadeite-albite dykes or sills intrusive into the peridotites and serpentines described above, and they may be designated (1) the Tawmaw dyke, (2) the Mienmaw dyke, (3) the Pangmaw dyke, and (4) the Namshamaw dyke.

The petrological account of these rocks is dealt with in subsequent pages, following the account of the mines.

The jadeite mines of the region can be classified as follows :

1. Outcrop mines.
2. Detrital boulder workings.
3. Jadeite workings in the Tertiary conglomerates.
4. The Uru Boulder Conglomerate workings.
5. Jadeite workings in the Uru *chaung*.

## 1.—Outcrop Mines.

### (a) The Tawmaw Jadeite-Albite intrusion.

**Discovery of the Jadeite at Tawmaw.**—The biggest outcrop of jadeite is at Tawmaw (25° 41′ 13″, 96° 15′ 28″), and was discovered about 54 years ago. The discovery was purely accidental. The story narrated to the author is that about sixty years ago a hunter named Ninjar of Sanhka reached the site of Tawmaw while hunting, and started cooking rice on a range of stones. One of the stones cracked, and proved to be valuable jadeite. Subsequently the Kachins started mining on the spot. The story recorded by Bateman, Assistant Superintendent, Kamaing, in his diary dated 28th February, 1907, is slightly different. " Some 26 years ago a Kachin who was on a hunting expedition shot at and wounded an elephant. He tracked the elephant to the spot now being quarried and found the animal dead there. He had removed its tusks and was trying to knock some of the flesh off them on a hard rock close by, when the weight of the tusk broke off a fragment of the rock which proved to be a valuable bit of jade. After a fashion, the development of this area has gone on since." The length and width of the proved outcrop at Tawmaw are a little over 300 and 200 yards respectively. The intrusion has been regarded as a dyke, but it is quite probable, as especially seen in the Kadondwin and elsewhere, that the injection took place in the form of a sill. The thickness is very irregular, probably depending upon the fissure into which the jadeite-albitite mass was intruded. The general trend is north-east–south-west which, however, swings between north-north-east–south-south-west and east-north-east –west-south-west.

**Old Kachin Workings.**—Many old Kachin workings are to be seen to the south-west of the Dwingyi (big mine). When the jadeite was first discovered here at Tawmaw there were only three or four feet of overburden in places, and the covering of serpentine was practically absent. The depth of the numerous deserted pits seldom exceeds six feet. The abandoned water-races used to sluice away the overburden are still to be seen.

The general section of the intrusion exposed at Tawmaw is as follows: at the top a very thick overburden of red earth represents the soil and subsoil formed by the weathering of serpentinised peridotites which form the country rock into which the jadeite-albitite mass is intrusive. Below the serpentinised peridotites lies a thin, earthy, very light-green chlorite-schist, which is locally called "*byindone*". The latter is underlain by a siliceous cherty mass which, in the mine, has the appearance of schistose serpentine. Below the chert comes an amphibole-schist or amphibolite (locally called "*shin*"). Next to the amphibolite is a banded amphibole-albitite rock which is underlain by albitite, and this in turn, by jadeite. Below the layer of jadeite the relationships of the rocks are seldom visible; in rare sections, however, the sequence may be repeated in the footwall, but albitite is not present as a rule below the jadeite, *i.e.* the latter may be directly underlain by amphibolite. In places albitite is absent altogether, but in others it is absent from the footwall only. It may occur at only one in ten localities, and commonly occurs at the top of the sill. In the Kadondwin, in the hanging wall albitite occurs in the middle and jadeite is found above and beneath it, while in the footwall jadeite occurs in lenses in the albitite.[1]

## Outcrop Mines of Tawmaw.

The outcrop mines are situated at Tawmaw. There are two of these: (1) the Dwingyi (meaning "big mine"), and (2) Kadon dwin ("*dwin*" in Burmese means a mine).

**The Dwingyi.**—The Dwingyi is certainly the more important of the two and the mine really consists of shafts and tunnels driven along the jadeite "dyke". There are six shafts in all, and in 1927 the mine subsided in one place making the total

[1] *Rec. Geol. Surv. India*, vol. lxii, 1929, p. 55.

number of surface openings seven. The shafts were originally put down by different people and are named after them.

In addition, there are a few small deserted pits which represent attempts at winning jadeite in the past. About 200 yards south-west of the Dwingyi, numerous old Kachin workings are to be seen. At this site jadeite was found almost at the surface; only three or four feet of over-burden had to be removed to reach it. Serpentine was practically absent. The depth of these pits did not exceed six feet.

**Methods of Mining.**—The mines are worked for only about three months in a year, *i.e.* from March to May, and all mining activity ceases with the advent of rains. During the rainy season the mines get filled up with water, and as a result the first operation when work is recommenced is to pump out this water. This is commenced in November or December and continues till the end of February. It may be noted in passing that since A. W. G. Bleeck's visit in 1907, mining methods have changed considerably. Kachins then emptied the mines by removing water with kerosene tins, but nowadays draining is performed by a steam pump.

The next operation is to clean the mines, *i.e.* to remove mud, etc., which has settled below water level. This is done by hauling it up in small petrol tins. When the mine is properly cleaned, operations can be started. The owners of the Dwingyi installed a compressed air drilling machine with which they work thin star-bit jack-hammer drills. Generally the drills are four-rayed, but sometimes they are six-rayed with a maximum diameter of one and three-quarter inches. A hole about six to nine inches in depth is drilled in the jadeite, and then pieces of jadeite are broken off by driving a wedge into the hole with big hammers. But when the compressed air-drilling machine is not operating the miners then work only with blunt chisels, wedges and hammers. The wedges are five inches in length and two inches in breadth. It is noteworthy that jadeite is a very tough and hard mineral and it is extremely difficult to break it. *In a few minutes a chisel or wedge loses its sharp edge.*

The primitive method of cracking jadeite with burning charcoal still continues. This practice is very injurious both to the mineral and to the miner. The former gets calcined as a result of this treatment while the value of the stone is considerably reduced on account of the development of cracks in it. The fumes of carbon monoxide emitted from the charcoal fires have their poisonous effects on the miners working underground.

### Kadon Dwin.

The Kadon dwin is run on more scientific and up-to-date methods by Mr. C. W. Chater of the Burchin Syndicate. The main vertical shaft, which is about fifteen feet square and fifty feet deep leads to drive No. 1, which is one hundred feet long 30° north of east and represents the hanging wall of the jadeite dyke. It opens out into a winze about 23 feet in depth and this leads to the stope No. 2 which represents the footwall of the dyke and is about 50 feet in length 10° east of north. The main shaft is entirely in serpentine and the drive No. 1 really represents the worked-out portion of jadeite along with the contact rocks, *viz.* "chloritic schist" and amphibolite in the hanging wall of the dyke. The average thickness of the jadeite here was about 4 feet. The winze or shaft No. 2 is entirely in albitite and the stope No. 2 has been driven in the footwall of the dyke. The albitite is traversed by vertical joints and these in some cases are filled with white veins. It is underlain by amphibolite and beneath this is the jadeite, the thickness of which varies from 5 to 7 feet. It is remarkable that the jadeite in the footwall occurs in the form of lenses. Up to 1928 three lenses have been worked out and at the close of the working season in May 1929 the fourth was being opened up. Amphibolite, and albitite with some albitite-breccia intervene between the successive lenses of jadeite. Below the latter come amphibolite and chloritic schist one beneath the other, and serpentine forms the bed-rock. The working face in 1929 was about 21 feet in width and on the left side, breccia, in which crushed fragments of jadeite, amphibolite and albitite are set in a calcareous matrix, was to be seen. The jadeite was seen dipping 30° east at the working face.

### Methods of Mining.

To pump out water a 12 H.P. Cochran boiler and pump with 5 inches suction and delivery pipes are used. Drilling is carried out with compressed air. To work the compressor, both steam- and oil-engines have been installed. These are also used for sawing timber employed in the mine and as firewood in the boiler. Star-bit pneumatic jack-hammer drills are employed, and holes generally 6 to 9 inches, but rarely 18 inches deep, are bored. Subsequently the rock is blasted with dynamite. As far as possible drilling is done in the country rock to expose the jadeite which is then broken down with wedges fixed in shallow bore-holes or with electric blasting wherever necessary.

During the working season water is pumped out of the mines thrice daily and the drilling is carried on day and night. At the time of the author's visit three compressed air drills were being worked by 5 coolies. The depth of the holes bored varies from 12 to 20 inches, but averages about 15 inches. Jadeite is a very tough mineral and C. W. Chater informed me that in one hour of drilling only 2·15 inches of jadeite can be bored. It therefore takes practically one shift drill of 8 hours to bore one hole. Generally 12 to 13 holes are bored and are then blasted with dynamite. Both jadeite and country-rock are hauled up in a skip worked by a steam hoist on a head-gear. A little truck carries the mineral and the gangue from the head-gear into the paddock and the dumps respectively.

**Industry declining at Tawmaw.**—The mining industry at Tawmaw is gradually declining, chiefly on account of the increasing depth of the mines; further, the old primitive methods of the Kachins cannot successfully cope with the present day condition of the mines. Unsettled conditions in China, the main consumer of jadeite, must be also partly responsible. The mines, in order to be productive, must be run on scientific and commercial lines, which requires capital, much beyond the means of poor Kachins. It is true that about 20 years ago, the output of jadeite was much greater than at present and three Mawoks (headmen), a Kachin, a Shan and a Chinaman had to be maintained. Even about five years ago, 400–500 miners were working at Tawmaw, but in 1927 and 1928, however, only some 50 to 60 miners had been engaged.

On the Tawmaw alignment are situated the three other outcrops of (1) Sarmamaw, (2) Malinkamaw, and (3) Sanhkamaw.

Sarmamaw.—It is interesting to record the discovery of the following outcrops of jadeite, hitherto unknown to science. About one mile south-west of Tawmaw (25° 41′ 13″, 96° 15′ 28″) is the outcrop of Sarmamaw which occurs on the right bank of a small stream called Sarma *hka,* named after the Kachin Sawbwa of the neighbourhood of Mogaung. At the top is an overburden 10 feet 2 inches thick and there is an inner pit about 13 feet deep with a diameter of about 10 to 15 feet. The jadeite appears to be bedded, dipping north-west, and a set of joints is developed at right angles to the bedding. In places the joints are only about one or two inches apart. At the top jadeite has altered to a soft whitish material, and the local Kachins, who tried to work this deposit, did not go deeper than the surface weathered material and deserted the locality considering that the " jadeite had not matured".

Malinkamaw.—Another locality where a jadeite outcrop was found is called Malinkamaw and is about 2 miles north-east of Tawmaw (25° 41′ 13″, 96° 15′ 28″). The rock here has greenish black inclusions of amphibole. The overburden measured only about 8 feet. Jointing in the north-easterly direction is well marked, and simulates bedding.

Sanhkamaw.—The third locality is situated in the Sanhka *hka*, about 2¾ miles north-east of Tawmaw. This locality does not leave a shadow of doubt as to the intrusive nature of the jadeite into serpentine. The thickness of the serpentine at the top is about 12 feet, and this is underlain by a soft chloritic schist about 1 foot thick. It thins out in a north-easterly direction. The trend of the outcrop here, too, is north-east to south-west with a north-easterly dip of 21°. The serpentine is highly jointed. Numerous small boulders of chromite are scattered about near the jadeite outcrop in Sanhka *hka.*

It appears that the outcrop of Dareemaw (25° 43′ 56″, 96° 18′ 35″) perhaps marks the extension of the outcrop described in the foregoing pages. It occurs near the old Kansi-Tawmaw footpath and there is a big central area with five or six smaller ones in the neighbourhood. At the top there is an overburden of red earth, about 10 feet thick, which is underlain by serpentine. Some rejected boulders of pale green jadeite were seen around the pits.

Another probable outcrop of jadeite lies N.W. of Mienmaw on the path which connects this village with the old Kansi–Tawmaw path. Several boulders of albitite ("*palun*") were seen lying near the pit and apparently the Kachins did not reach the jadeite lying underneath the albitite.

### (b) The Mienmaw dyke.

On the Mienmaw dyke are situated the outcrops of Shammonmaw (25° 43′ 39″, 96° 20′ 40″), Mienmaw (25° 43′ 24″, 96° 20′ 40″), and Sharoinawngmaw (25° 44′ 59″, 96° 20′ 40″). The two extreme outcrops are separated by a distance of 1½ miles in a north–south direction.

**Shammonmaw.**—The outcrop of Shammonmaw (25° 43′ 39″, 96° 20′ 40″) is marked by two old workings aligned in a north–south direction. The northern one is the bigger and is 70 feet long, 30 feet wide and 25 feet deep and was filled with water at the time of the author's visit. The Kachins call it "Mikehtaingmaw" or "Mai-tingmaw," after the tree of *Mesua ferrea* that grows on these hills.

**Mienmaw.**—The important locality of Mienmaw (25° 44′ 24″, 96° 20′ 40″) has been worked spasmodically by several people. There is a heavy overburden of red earth with abundant iron concretions, 25–30 feet in thickness, but nothing about the relationships of the rocks of the dyke could be seen since the old workings have been filled up with red earth washed from above; only serpentine and chloritic schist (*byindone*) could be seen in places. In one place chrome-epidote was observed with albitite ("*palun*") and this is a favourable indication of the occurrence of green jadeite in the vicinity: chrome-epidote is formed where chromite is present in serpentine, and the associated minerals, albite and jadeite, are coloured green as a result of absorption of the epidote.

**Sharoinawng-maw.**—The workings of Sharoinawng-maw (25° 44′ 59″, 96° 20′ 40″) lie deserted now, though a Chinaman from Hmawlu, near Zeba, worked it for two years some time ago and employed 50 to 60 coolies both here and at Wikhomaw. After his death in China the work had to be abandoned. All that can now be seen is a deep, twenty-foot square tank filled with water.

### (c) The Pangmaw dyke.

The third dyke with a N.W.–S.E. extension for a little over three quarters of a mile comprises the outcrops of Pangmaw, Wikhomaw and Kyobatmaw.

**Pangmaw.**—The old workings known as Pangmaw are found 80 paces N.E. of the Pang *hka,* where it is crossed by the Namshamaw–Mienmaw path, where ten small deserted pits are to be seen. Jadeite and albitite are both found here with inclusions of amphibole. The serpentine is rendered fibrous near the contact, and occurs as detached boulders around the pits. In the neighbourhood of the jadeite workings chromite and iron-ore boulders also occur in a small water course.

**Wikhomaw.**—About half a mile N.W. of Pangmaw 13 old pits are to be seen, which mark the jadeite outcrop of Wikhomaw. About four years ago, as mentioned above, a Chinaman from Hmawlu mined it for three years. The biggest pit, which is really a combination of three smaller ones, is about 60 feet in length in a north-north-east–south-south-west direction. The breadth of the workings is 32 feet.

At the top there is an overburden of red earth about 6 feet in thickness. It is underlain by schistose and talcose serpentine. The pit is 18 feet deep, but at the bottom 3 feet of water covers the jadeite zone. A little to the west of this pit there is a small dry stream, where jadeite is exposed dipping west in the same direction as the serpentine.

**Kyobat-maw.**—The old workings of Kyobat-maw are about one quarter of a mile north-west of Wikhomaw. Besides several small deserted pits there is a long trench cut in the serpentine, about 100 yards in length, 10 feet in width and about 25 feet in depth in places. The trend of the cutting is east–west but in places swings between E.N.E. and W.S.W.

### (d) The Namshamaw dyke.

The following outcrops of jadeite are situated in the neighbourhood of Namshamaw (25° 45′ 31″, 96° 22′ 28″) :

(1) Namshamaw.
(2) Mawsitsit.
(3) Wayntmaw.

This dyke[1] strikes in the same direction as the Pangmaw dyke, with a W.N.W.–E.S.E. trend.

**Namshamaw.**—The jadeite workings of Namshamaw are situated near the confluence of the Namsai and the Uru *chaung*. Blocks of jadeite of irregular shape, which seem to have travelled little, occur in red earth formed by the decay of the serpentine. Very likely the jadeite boulders excavated here represent disintegrated portions of a dyke which has either not been exposed yet or lies a little to the west. Early in 1929 Chinamen were working for jadeite here.

A little to the north of Namshamaw lie the deserted workings of Konfimaw, marking an occurrence of red jadeite (*konpi*).

**Mawsitsit.**—The deserted workings of Mawsitsit lie about half a mile west (slightly north) of Namshamaw in a stream and adjoining it. The old pits are lying filled with deep water, thereby concealing the relationships of the rocks. The local people recognise two varieties:

1. *Mawsitsit* (chromo-jadeite) of dark green colour.
2. *Kyet tayoe* (chrome-garnet) bright green colour.

Of the two, *Mawsitsit* finds most favour as a semi-precious stone.

**Wayutmaw.**—The jadeite outcrop of Wayutmaw is about a quarter of a mile west-north-west of Mawsitsit.

At the top there is an overburden about 6 feet in thickness which overlies the weathered jadeite, and the mines apparently did not go much deeper than that. A number of old pits are still to be seen. Fairly big boulders of chromite were observed near this locality.

## 2. Detrital Boulder Workings.

Two localities in the neighbourhood of Tawmaw were worked for detrital jadeite boulders in the past: (1) Pan Din Maw (25° 41′ 17″, 96° 16′ 23″), (2) Paim-ma-chait (25° 38′ 51″, 96° 15′). These very shallow or almost surface workings deserve separate treatment, since they constitute a class by themselves.

(1) **Pan Din Maw.**—The jadeite-bearing locality of Pan Din Maw was discovered by a Kachin about 20 years ago, it was

[1] Term used in general sense.

worked for only one year about six years ago, but as valuable mineral was not found in any quantity, the pits were deserted. The latter can be approached by a wood-cutter's path, bifurcating from the main Tawmaw-Lonkin road, a little over a furlong E.S.E. of mile 41, marked on the map (92 C/6). A number of very shallow pits are to be seen on the left bank of a small un-named stream, flowing W.N.W.–E.S.E., which are a little over a mile E.N.E. of the spot where the path leaves the main road.

The pits are only 2 to 3 feet deep and no jadeite occurs at a depth of 4 feet. It is found in the form of partially worn boulders along with those of serpentine. It is very likely that these boulders were detached from the dyke exposed at Tawmaw and transported for some distance before being embedded in the red earth of their present home.

(2) **Paim-ma-chait.**—The second locality is situated about 2½ miles S.S.W. of Tawmaw, and lies one-third of a mile north-west of the Tawmaw–Lamong road. About 30 years ago Kachin hunters discovered this place and some 20 years ago it was the scene of mining activity for one year, but it was ultimately abandoned for the same reason as Pan Din Maw.

Between 40 and 50 old pits are to be seen and their diameter varies between 3 and 4 feet, the maximum in rare cases being 6 feet. Their depth varies from 3 to 4 feet and in rare cases it is as much as 6 feet. They are all on the right bank of the Paim-ma-chait *chaung* and boulders of jadeite are also found in the bed of the stream itself. Jadeite, as in the previous case, is found in the form of boulders and to test the quality of the stone, they were broken with hammers; very big ones were cracked with fire. Amphibole occurs as inclusions in the jadeite. I was told that only one stone, of the value of Rs. 180/-, was found along with a number of smaller ones valued at about Rs. 20/- each. A number of chromite boulders were discovered scattered in the stream.

### 3. Jadeite workings in the Tertiary Conglomerates.

**A. In the neighbourhood of Kansi** (25° 47′ 1″, 96° 22′ 48″) the following workings occur: (1) Pangmamaw, (2) Mutantumaw, (3) Samhtanmaw, (4) Shilamaw, (5) Sanimaw, (6) Aungbilemaw and (7) Hpelaimaw.

All these workings except the last, which was not visited by the author, lie in the Tertiary conglomerates, and the torrential streams descending from the neighbouring hills of serpentine with jadeite must have been responsible for their deposition.

(1) **Pangmamaw.**—The old workings of Pangmamaw are to be seen in the Pangma *hka* and its tributaries. Kachins worked the banks of the stream and sometimes the adjoining ground for boulders of jadeite in the past. The workings are situated in the Tertiaries, which comprise soft, bluish, greenish and yellowish sandstones, shales, coarse grits and conglomerates. The last include both coarse and fine varieties, and quartz, quartzite, schists, serpentine and chromite take part in their constitution. Some of the boulders of serpentine are huge in size and must have been derived from the hills on the east where the Pangma *chaung* takes its source; but the Tertiaries must have been in position prior to the establishment of the present drainage system.

Some of the jadeite boulders found here, according to local information, were huge—about the size of a buffalo—proving thereby that the boulders had not travelled far from their original source.

(2) **Mutantumaw.**—One of the main tributaries of the Pangma *chaung* is called the Mutantu *hka* and hence the name of the workings. These workings have been deserted, though formerly Kachins, Shans and Chinese worked here. It is reported that the quality of the jade is not good and is rather scarce.

(3) **Samhtanmaw.**—The workings of Samhtanmaw lie in a small tributary stream (of the same name) of the Pangma *hka*, which joins the Uru river near Kansi.

(4) **Sanimaw.**—The workings of Sanimaw are situated in the Sani *hka*, east of Kansi. The overburden, about 6 feet in thickness, is underlain by the boulder bed, about 4 feet in thickness, consisting mostly of partially worn boulders of serpentine and crystalline schists. The boulders of jadeite itself are angular and irregular in shape showing that they have not undergone much transport. Several old pits are to be seen in the neighbourhood of the stream.

(5) **Shilamaw.**—The workings of Shilamaw lie in the stream of this name which joins the Uru river below Kansi.

(6) **Aungbilemaw.**—The old jadeite workings known as Aungbilemaw lie in the lower course of the Seintu *hka*.

**B. In the neighbourhood of Lonkin** (29° 39′, 96° 22′).

(1) **Kademaw.**—The workings of Kademaw (25° 39′ 17″, 96° 20′ 23″) lie near the unimportant Kachin village of Namayang near the 34th mile marked on the Kamaing–Tawmaw road. The mining is carried on along the banks and in the vicinity of the Namayang *hka*. At the top there is generally an overburden of alluvium that is underlain by the Boulder Conglomerate, which is mined for boulders of jadeite. The Chinese in 1929 carried on some underground mining, by way of driving tunnels.

(2) **Mawmaik-ak.**—The workings of Mawmaik-ak are situated on both sides of the Namayang *chaung* between Kademaw and Masamaw, just before the schists crop out in the stream.

(3) **Masamaw.**—The workings of Masamaw (25° 39′ 33″, 96° 19′ 58″) are to be seen adjoining the left bank of the Masa *hka* which is an important tributary of the Ningma *hka*. As usual there is an overburden consisting of red earth capping the conglomerate. Mining is carried on by means of *mayaws* during the rainy season. The overburden is sluiced away by booming with water obtained from springs and small streams issuing from the sides of the hill. As is to be expected the thickness of the overburden increases as we recede from the Masa *hka*. It is remarkable that they are redigging the old pits. Formerly they went only about 12 feet in depth, in 1929 they had gone about 25 feet deep and were still continuing.

From the disposition of the Tertiary jade-bearing conglomerate in the neighbourhood of Masamaw and elsewhere it is apparent that the great bulk of it must have been deposited by torrential streams from the adjoining hills flowing into the Uru *chaung*. Similarly the torrential streams with the Uru *chaung* must have played an important part in the deposition of the Uru Boulder Conglomerate. (See p. 41).

(4) **Maraw-maw.**—This is a new locality worked in 1929 and lies about 150 yards north-north-west of the Kachin village of

Marawgahtaung (25° 38′ 49″, 96° 19′ 36″). The workings lie on the hill-slope adjoining the right bank of the Ningma *hka*. At the time of the author's visit in November 1928 not a single pit was to be seen; but on his return in the beginning of May 1929 he found at least one thousand deserted pits. A few Kachins and Shan-Burmans were still working. During the 1929 season four stones of the value of a few thousand rupees had been found besides several others of smaller value. The thickness of the Tertiary boulder conglomerate here is rather small and the bed-rock, viz., the schists, appears close to the surface. Some of the pits are hardly 4 feet deep. Lower down almost all the pits have been dug in the schists with obvious results. On both banks of the Ningma *hka* some old pits were to be seen, some in the schists and a few in the boulder conglomerate adjoining the stream. In all about half the total number of pits had been dug in the schists with no return whatever for money, time and labour.

The material for the jadeite-bearing boulder conglomerate apparently came from the serpentine deposits of Tawmaw; and the epidiorites and quartz boulders, which constitute the rocks immediately adjacent to the conglomerate, are predominant in its constitution.

(5) **Maw-sisa.**—The workings of Maw-sisa mostly lie in the bed of the stream of this name which joins the Uru river about ¾ mile south of Warong village (25° 39′ 13″, 96° 21′ 15″). These workings start from the junction of the Uru and the Maw-sisa *chaung* and continue for about a mile inwards. The pits are rather shallow, since the hard, consolidated conglomerate makes its appearance very near the surface. Old deserted *mayaws* (water-channels) are to be seen in places.

It is remarkable that as soon as hard consolidated conglomerate is reached, which cannot be mined with crowbars and picks, mining is stopped. It would be worth while to prove favourably or otherwise the presence of boulders of jadeite in this hard conglomerate as well, otherwise for want of better organisation and modern mining methods vast reserves of jadeite may remain buried for a long time to come.

(6) **Saung Chein-maw.**—Some old pits are to be seen at the confluence of the Saung Chein and the Uru *chaungs*.

(7) **Ngopinmaw.**—The workings of Ngopinmaw are seen about a quarter of a mile north-east of Kademaw on the way to Sanhka (25° 41′ 8″, 96° 20′ 57″).

(8) **Sanhkamaw.**—The numerous old jadeite workings of Sanhkamaw are situated near the Kachin village of Sanhka (25° 41′ 8″, 96° 20′ 57″), in the area enclosed by the U-shaped bend of the Sanhka *chaung* near its mouth. They also extend along the Sanhka *hka* for a distance of about one mile from its confluence with the Uru river. Old workings also occur in the lower course of the Wage *hka* which joins the Sanhka *chaung* about a quarter of a mile south-west of Sanhka.

**C. In the neighbourhood of Hwehka.**

Tertiary jadeite workings exist in the neighbourhood of Hwehka within a radius of about 2 miles (see Fig. 2). As stated above, bands of conglomerate embedded in the Tertiary sandstones and shales are mined for jadeite (see Plate II, Fig. 2), in a number of places, the names of which are given below :

**D. In the neighbourhood of Kadonyat** (25° 3′ 20″, 96° 15′ 46″).

1. Mabu-maw (north-west of Kadonyat), in the Mabu *chaung*.

2. Sawbwagyaungmaw (deserted). These old workings lie in a small tributary stream of the Kadonyat *chaung*, about one-third mile north of Kadonyat.

**E. In the neighbourhood of Hwehka** (25° 29′ 3″, 96° 16′ 43″).

3. Hwehkamaw, situated in the neighbourhood of Hwehka village.

4. Hmawlugyaung-maw. These workings are situated in a small dry stream, west of Hwehka village.

5. Sanimaw.

6. Hmowtaung. These quarries have a working face about 30 feet high and near the crest of the hill, about half a mile north of the present Rest House of Hwehka. One old underground working was seen—which had fallen in.

7. Mawnanhka (deserted).

The workings No. 6, 7 and 8 are situated on the hill north of Hwehka.

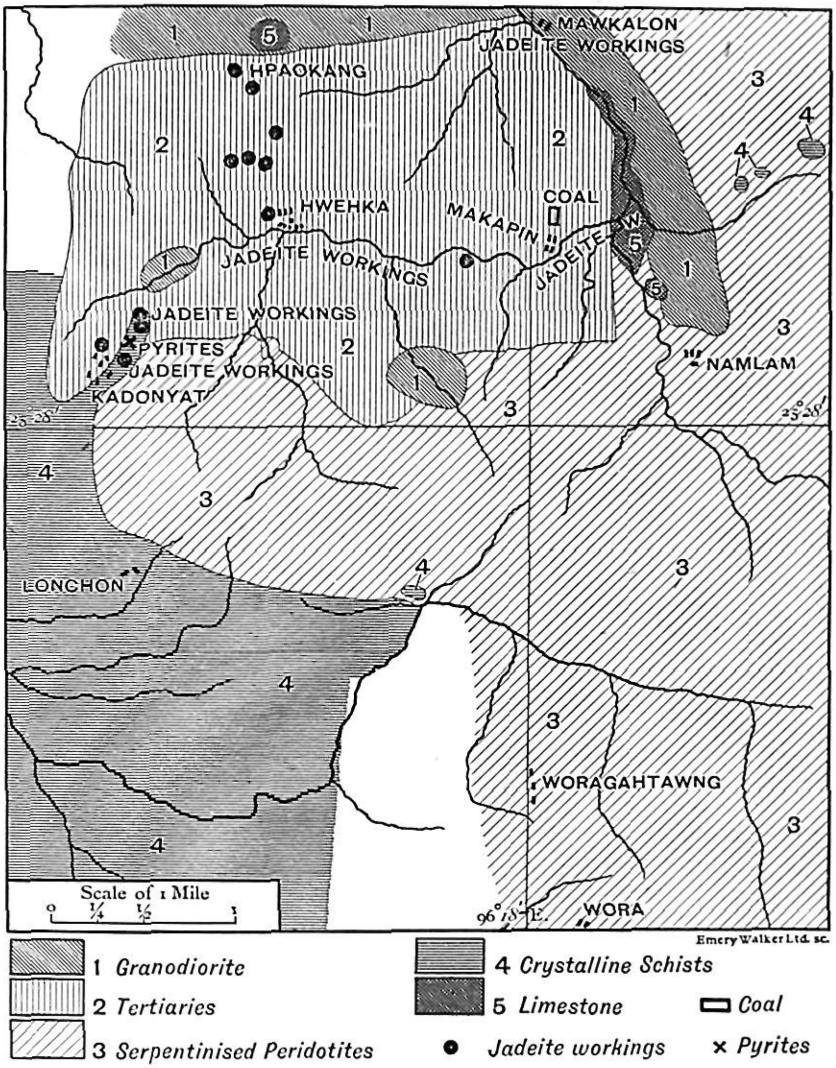


FIG. 2.—Sketch map showing jadeite workings in the neighbourhood of Hwehka.

8. Natyedwin is situated a little north-west of Hpaokang village, close to the Mamon-Hwehka road. Only one pit was being worked at the time of the author's visit.

9. Ohminwa-maw (deserted), situated in the stream of the same name.

**F. In the neighbourhood of Makapin** (25° 28′ 53″, 96° 18′ 4″)

10. Zibyugon (25° 28′ 45″, 96° 17′ 41″), about a mile east of Hwehka on the right bank of Hwehka *chaung*; worked throughout the year. A very interesting section of the Tertiaries is exposed in these workings. At the top there is a wash from the Tertiaries mostly of a conglomeratic nature, about 22 feet thick, which is underlain by weathered sandstone, yellowish in colour having a thickness of 2 feet 2 inches. Below this comes a clay which is pebbly in places while pieces and small stumps of lignite are arranged in rows in it. It overlies the main jadeite-bearing conglomerate which has a thickness of about 3 feet and is succeeded by hard coarse sandstones, locally called " Phah " (meaning bed rock). This is too hard for the miners to quarry.

11. Mawgyaungwa (deserted). These old workings exist in the Mogyaung *chaung*, a tributary of the Hwehka *chaung* which joins the latter from the south, a little west of Makapin.

12. Makapin. These workings are said to be the oldest and according to the local inhabitants, the best jadeite comes from them.

13. Namlanmaw, comprises a few pits in a small dry stream east of Makapin, which forms the Makapin-Namlan footpath. They are only worked during the dry season.

14. Satpya-maw (deserted), situated close to the confluence of the Satpya and Hwehka *chaungs*.

15. Mawnantee, situated between Mawkalon and Satpyawa and worked only during the dry season.

**G. In the neighbourhood of Mawkalon** (25° 29′ 55″, 96° 18′).

16. Nankatmaw, near Mawkalon, worked throughout the year.

17. Metlinwa-maw (deserted), near Mawkalon.

18. Mawkalon (see Plate II, Fig. 1). This is the biggest centre of mining activity in the vicinity of Hwehka at the present day and the industry is continued all the year round.

19. Uke-maw. These workings lie in the Uye *chaung* which meets the Hwehka *chaung* from the west near Mawkalon. They are worked throughout the year, but more especially during the rainy season.

PLATE II.

FIG. I.—A JADEITE-WORKING AT MAWKALON IN THE BED OF THE STREAM.

Notice the digging of the boulder conglomerate. The useless boulders and débris are dumped away on the sides of the working, and the water is pumped out by means of bamboo pipes.

FIG. 2.—SHOWING THE JADEITE WORKINGS AT HWEHKA.

*The sides are barricaded with bamboos to prevent them from falling in.*

20. Patit-maw, north of Mawkalon in the Hwehka *chaung* is worked only during the dry season.

In the vicinity of Hwehka the slopes of the hill north of the village are being worked (see Plate II, Fig. 2). It appears that quarrying was commenced at the base of the hill and has gradually proceeded upwards until at the present day the Kachins are working almost at the top, about 550 feet above the bed of the Hwehka *chaung*. Huge dump-heaps and numerous deserted workings are to be seen on the road to the present workings. The different claims which are generally 16 feet square or 10 by 20 feet in extent are defined by bamboo barricades propped by wooden posts, to prevent the collapse of the sides, composed of rather loose sandstones, shales and conglomerate of the adjacent claims. These workings are in the nature of shallow wells. Sometimes open quarrying is also done and the working face is about 18 to 20 feet high. The bands of jadeite-bearing conglomerate, as remarked already, are intercalated in the sandstones and shales. Sometimes a number of these bands are present, for example, at Sani-maw there are three bearing distinctive local names.

The lowest layer is the most productive. The thickness of the conglomerate bed varies from 1½ to 6 feet. Sometimes the boulders forming the conglomerate are of huge size, a few feet in diameter. It is very remarkable that the Tertiary conglomerate is very rich in serpentine, and the name serpentine-conglomerate would not be a misnomer.

**Methods of mining.**—The methods of mining in this area are almost the same as in the case of the Uru Boulder Conglomerate workings. Here too both the hill sides and river-bed workings exist, but the former are more numerous.

Mining, as usual, is done with crowbars and *mamooties*. In some claims four men work together: one of them does the digging with a crowbar, the second fills up the baskets and the remaining two dump the débris. For bailing water bamboo pumps (see Plate II, Fig. 1) are used, but at Sanimaw the tedious process of removing water in kerosene cans still prevails. In places a sort of lever lift is used for hauling up the débris from the pits.

With regard to the source of the jadeite found in the Tertiary conglomerates of Hwehka, the author has concluded that the stone cannot possibly have come from the Tawmaw dyke and that there must have been another primary occurrence of the mineral associated with the peridotites and serpentines of the south, which has either been denuded away or lies concealed in the impenetrable jungle.[1]

### 4. The Uru Boulder Conglomerate Jadeite-Workings.

The Uru Boulder Conglomerate is worked for jadeite in numerous places and these workings can be classified as follows:

1. Stream-bed workings, where mining is possible throughout the year.

2. Hill-side workings, where the rock is quarried during the rains, which help in sluicing away the overburden and the matrix of the conglomerate. These hill-side workings exist in the neighbourhood of Balakha (25° 37′ 30″, 96° 17′ 1″), the deserted village of Manna (25° 36′ 43″, 96° 16′ 15″), Nammaw (25° 38′ 20″, 96° 15′), etc.

Stream-bed workings for jadeite are really too numerous to mention and are situated on the banks or in the bed of the Uru *chaung* and its tributaries. They commence from near Kansi (25° 46′ 54″, 96° 22′ 47″) and continue intermittently right down to Haungpa.

The following section is generally observed in the Boulder Conglomerate workings for jadeite.

I. Alluvium at the top, of variable thickness.

II. A layer of pebbles and gravel which the miners call "*Kadi Kyaw.*"

III. Boulder Conglomerate, which is locally called "*Kyauk Kyaw.*"

IV. Sand-rock with boulders, locally known as "*Thai Kyaw,*" which is generally gold-bearing and, according to the miners, jadeite boulders of better quality are found in this layer. When this layer is absent, it is thought the place is not worth working, and valuable finds are not expected.

V. Bed-rock, locally called "*Phah*" and all mining is stopped when it is reached. Jadeite boulders are found only in III and IV.

[1] *Rec. Geol. Surv. Ind.* vol. lxii, 1929, p. 57.

PLATE III

A JADEITE-WORKING IN THE URU BOULDER CONGLOMERATE, PAN-TINMAW, OPPOSITE THE CONFLUENCE OF THE URU AND THE MOWMOAN *CHAUNGS*

**In the neighbourhood of Hpakan** (25° 36′ 38″, 96° 18′ 40″). Hpakan is an important mining centre and workings for jadeite exist in several neighbouring localities listed below :

1. Pantinmaw, opposite the confluence of the Uru and the Mowmoan *chaungs*. Here some fine typical sections of the Boulder Conglomerate are to be seen (see Plate III).

2. Monyin Chan, about 1⅓ miles east of Hpakan on the right bank of the Uru *chaung*.

3. An-ma. These workings are situated ⅝ths of a mile east of Hpakan on the left bank of the Uru river. There is a thick capping of alluvium, 14 ft. thick, at the top of the Boulder Conglomerate and the thickness of the latter is 9 feet. At the time of my visit women were washing for gold here.

4. Mowmoan *chaung*, near Mowmoan village (25° 36′ 53″, 96° 19′ 11″) and in the lower course of the stream of the same name.

5. Mowmoan Chaungbya (upper workings). Jadeite workings extend right up to the source of the Mowmoan *chaung* and in some of its tributaries.

6. Mow-Maung, in the stream of the same name, north-west of Hpakan (25° 36′ 38″, 96° 18′ 40″).

7. Shulunghka. In the neighbourhood of Shulunghka (25° 36′ 23″, 96° 17′ 28″) there are both stream-bed (in Sabyi *hka*) and hill-side workings. From the number of deserted pits and water-leads seen here it appears that jadeite mining must have been more flourishing years ago than it is at the present day.

8. Kalamaw (25° 36′ 55″, 96° 16′ 55″). These workings are situated a mile above Shulunghka and lie in the Sabyi *hka* stream. Old iron pipes are still to be seen lying about here. The village is surrounded by high steep cliffs of the Boulder Conglomerate on all sides.

9. Sabyi and Sabyi Wa (25° 37′ 24″, 96° 16′ 15″) (both deserted).

10. Hpakangyi. A little over one-third of a mile E.S.E. of Hpakan (25° 36′ 38″, 96° 18′ 40″), on the left bank of the Uru *chaung*. Opposite these workings are precipitous cliffs about 200 ft. high above the level of the river bed.

11. Mowtaung, a little below Hpakangyi.

**In the neighbourhood of Sankywe** (Sanchói) (25° 35′ 25″, 96° 17′ 47″)

12. Sankat, about $\frac{7}{10}$ths of a mile—some 5° west of South of Hpakan, on the right bank of the Uru *chaung*.

13. U-mar, about $\frac{4}{5}$ths of a mile N.E. of Sankywe (25° 35′ 25″, 96° 17′ 47″) on the left bank of the Uru *chaung*.

14. Sankywe (marked Sanchoi on the map, 92 C/6).

**In the neighbourhood of Parpyin** (25° 35′ 21″, 96° 16′ 40″).

15. Mena-aik, a little over $1\frac{1}{2}$ miles E.N.E. of Mamon (25° 35′ 10″, 96° 15′ 57″). This locality was once worked for gold in addition to jadeite.

16. Nampagon, a little above Parpyin.

17. Parpyin. In one pit near the stream the following section was observed :

| | |
|---|---|
| 3. Sandy alluvium, false-bedded - | - 9 ft. |
| 2. Fine gravel-bed - - - | - 2 ft. |
| 1. Boulder-bed, mined for jadeite | - 19 ft. |

**In the neighbourhood of Mamon** (25° 35′ 10″, 96° 15′ 57″).

18. Thabeymaw, about half a mile north-east of Mamon (25° 35′ 10″, 96° 15′ 57″) on the right bank of the Uru *chaung*.

19. Mamon, in the neighbourhood of the village of Mamon.

20. Meikkye.

21. Htintingyi.

22. Htingtingale.

23. Sabwe, in the Sabwe *chaung*.

The workings 20–22 all lie along the Uru *chaung* below Mamon.

**In the neighbourhood of Nammaw** (25° 38′ 20″, 96° 15′).

24. There are several important jadeite workings in the neighbourhood of Nammaw.

**In the neighbourhood of Haungpa** (25° 30′, 96° 6′ 15″).

The following important workings for jadeite occur in the neighbourhood of Haungpa (Fig. 3).

25. Namasabein.

26. Mawkadi.

27. Tamkhan.

28. Tape.

In this region Tamkhan is the most important mining centre and the area enclosed by the inverted U-shaped bend of the stream (Uru *chaung*) is worked. The mining methods are the same as in the north.

The interesting workings of Sietaung must not be omitted. They are situated about 2 miles south-south-east of Saingmaw (25° 35′, 96° 17′ 30″) or about one-fifth of a mile south-west of the confluence of the Nammaw and Hwehka *chaungs*. This locality was worked for precious stones even during the time of the Burmese kings but was subsequently deserted. About 9 years ago, jadeite mining was renewed and one stone was sold

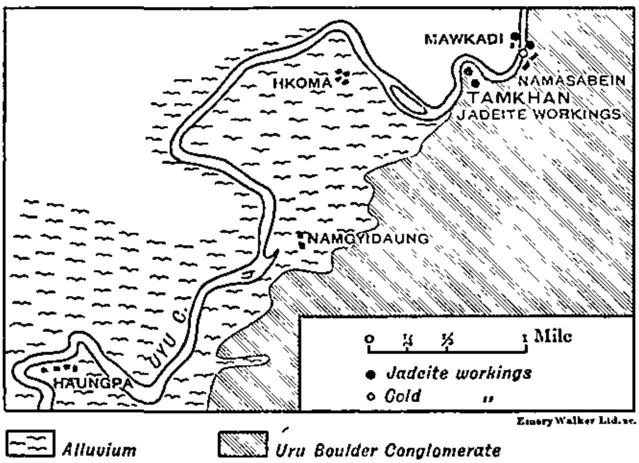


FIG. 3.—Showing jadeite and gold workings in the neighbourhood of Haungpa.

for Rs. 6000/-. There are several deserted pits numbering about 1000. The workings are situated on both sides of the Hwehka *chaung*, however, those on the left bank constitute the majority. The thickness of the Boulder Conglomerate varies from 1½ feet to 6 feet at the most. In 1929 only one pit was being worked in which the overburden constituted 13 feet 5 inches, underlain by a boulder-bed 6 feet in thickness, which overlies the serpentine forming the bed-rock; but a comparatively larger number of people are engaged in the industry during the rainy season. It appears that this Boulder Conglomerate was deposited by the Hwehka *chaung* since it disappears at a distance of about 100 yards from the stream. The nature of the boulders is also different from those seen towards the north the majority of them being of granodiorite, diorite, granophyre and quartz.

**Methods of mining.**—Before commencing mining, Jade-Nats (Spirits) are propitiated by almost every worker, irrespective of his nationality. It is believed that if the *Nats* are pleased, the miners will make valuable finds quickly.

Generally, at the top is some overburden (alluvium), which is sluiced away by a water-race formed by diverting the channel of a stream. Then the Boulder Conglomerate is quarried with picks, crowbars and *mamooties*, so that a steep face is obtained. Water dammed a little upstream is made to flow as a race over this steep face, which washing away all the earth, leaves the boulders clearly exposed to view. They are carefully examined for jadeite. If water is not available from the stream, then a pit is dug in its bed, and it is replenished from the Boulder Bed. Then it is pumped out by an ingenious contrivance, described below, on to the desired place. On the other hand, in the bed of the Uru *chaung* and some of its tributaries, water almost invariably fills the pits dug in the Boulder Conglomerate, so that to carry on mining it is necessary to empty the pits. For this purpose a long bamboo is used as a pipe or pump cylinder in which a wooden plunger with a T-shaped handle at the outer end and a leather valve at the inner is worked It is remarkable how it exhausts the water so rapidly. The number of pumps employed in a pit depends on the amount of water to be bailed out. At Mawkalon, in an exceptionally large pit as many as 8 or 9 pumps have to be worked simultaneously.

It must be noted here that the work is not all carried out on up-to-date scientific lines, but in the old primitive fashion. The people work blindly believing entirely in their luck.

The miners are not all scrupulous in selecting the locality they propose to work. In this they are entirely guided by instinct. If in a particular spot, some valuable find is made, almost all the coolies flock to it. Such methods very often result in considerable wastage of labour and money, as no record is kept of the worked-out places. Not infrequently the same spot is dug over three or four times with obvious results.

Another important drawback is that the work is not systematic. Their present methods result simply in picking up the best pieces of jadeite and neglecting entirely the less valuable ones. In fact the whole industry requires reorganisation.

In the Boulder Conglomerate workings every race and nationality is represented. Kachins, Shans, Burmans, Chinese and occasionally an Indian are to be seen: the Shans probably form the majority. The labour is financed by jadeite merchants.

### 5. Workings in the Uru Chaung.

Occasionally jadeite workings are situated in the Uru *chaung* itself. A stray labourer might search for jadeite boulders from the bed of the stream. This is a laborious task as the man has not uncommonly to stand in water, about thigh deep all the time while, as a rule, the reward of his exertions does not arrive very promptly.

In places the Shans dive in the Uru *chaung* in search of the precious stone. This method is used at Mámon and Chaunglon. The latter locality is about a quarter mile east-north-east of the confluence of the Nammaw and the Uru *chaungs.*

## PETROLOGY OF THE JADEITE-ALBITE ROCKS.

The jadeite-bearing intrusions consist of the following three rock types, which grade into one another jadeitite, albitite and amphibolite.

**The Jadeitite** is an exceedingly tough rock, normally white, but it is irregularly streaked and spotted with emerald-green by chromite, apple-green by iron and lavender-blue by manganese. In some cases the rock is monomineralic, and this is the densest type with a specific gravity of 3·34, and furnishes practically all the precious gem material.

In other specimens large crystals of amphibole are present in addition to the jadeite (see below). Intermediate in composition between the pure jadeite rocks and the albitites are the albitic jadeitites, containing variable quantities of albitite. With decreasing jadeite these grade into albite rocks or albitites.

**Chemical Composition.**—The range of chemical composition of the jadeitites is indicated by the analyses listed below, which were prepared for Professor Lacroix by M. Raoult.[1] The calculated analysis of pure jadeite is included for comparison.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| $SiO_2$ - | 59·40 | 59·84 | 58·18 | 58·64 | 58·46 | 57·48 | 51·10 |
| $Al_2O_3$ - | 25·25 | 24·48 | 21·40 | 23·50 | 24·21 | 21·81 | 27·55 |
| $Fe_2O_3$ - | — | — | 0·29 | 0·21 | 0·48 | 0·12 | 0·23 |
| FeO - | — | 1·20 | 2·53 | 0·85 | 0·76 | 1·59 | 1·28 |
| MnO - | — | — | 0·08 | — | 0·03 | 0·05 | 0·08 |
| MgO - | — | 0·81 | 2·65 | 1·45 | 0·39 | 3·21 | 1·10 |
| CaO - | — | 1·42 | 3·82 | 1·88 | 1·74 | 2·08 | 2·32 |
| $Na_2O$ - | 15·35 | 11·66 | 9·95 | 11·93 | 12·71 | 12·35 | 12·86 |
| $K_2O$ - | — | 0·35 | 0·16 | 0·55 | 0·35 | 0·25 | 1·22 |
| $TiO_2$ - | — | — | — | — | — | — | — |
| $P_2O_5$ - | — | — | — | — | — | — | 0·04 |
| $H_2O+$ | — | 0·17 | 0·50 | 0·86 | 0·69 | 0·55 | 1·49 |
| $H_2O-$ | — | 0·11 | 0·19 | 0·36 | 0·11 | 0·22 | 0·45 |
| | 100·00 | 100·04 | 99·75 | 100·23 | 99·93 | 99·71 | 99·72 |
| Density | — | 3,276 | 3,348 | 2,685 | — | — | 3,284 |

1. Theoretical jadeite. NaAl $(SiO_2)_3$.
2. Jadeitite with jadeite in long white rods, Tawmaw; analyst, M. Raoult.
3. Apple green jadeitite, Sietaung.
4. Highly albitic part of a jadeitite from Kadon dwin.
5. White jadeite in long white rods. Analyst, Raoult.
6. White jadeite, spotted green, Dwingyi.
7. Nepheliniferous jadeite, Tawmaw.

The normative composition of the above rocks, except No. 5, as given by Lacroix is tabulated below:

| | (1) | (2) | (3) | (4) | (6) | (7) |
|---|---|---|---|---|---|---|
| Orthoclase - - | — | 2·22 | 1·11 | 3·34 | 1·67 | 7·23 |
| Albite - - - | 64·97 | 69·17 | 60·26 | 60·78 | 56·07 | 33·40 |
| Anorthite - - | — | 6·95 | 13·07 | 8·62 | 3·34 | 11·40 |
| Nepheline - - | 34·93 | 15·90 | 13·06 | 21·87 | 26·13 | 40·68 |
| Corundum - - | — | — | — | — | — | 1·02 |
| Wollastonite - | — | 2·35 | 2·44 | 0·35 | 3·02 | — |
| Enstatite - - | — | — | 1·40 | 0·20 | 2·10 | — |
| Ferrous silicate - | — | — | 0·92 | 0·13 | 0·66 | — |
| Forsterite - - | — | 1·40 | 3·64 | 2·38 | 4·13 | 1·96 |
| Fayalite - - | — | 1·73 | 2·75 | 1·02 | 1·53 | 1·84 |
| Magnetite - - | — | — | 0·46 | 0·23 | 0·46 | 0·23 |

[1] Lacroix, A., "La jadeite de Birmanie, les roches qu'elle constitue ou qui l'accompagnent, composition et origine," *Bull. Soc. franç. Min.*, vol. liii, 1930, pp. 216-254.

**Physical Properties.**—Prismatic cleavage in Burmese jadeite is very well-marked and partings in several directions are also distinct, including those parallel to (100) and (010).

Interpenetration twinning on a prism face, and simple twinning are observed under the microscope.

The specific gravity of the jadeite ranges from 3·264 to 3·336 and the average of 12 determinations was 3·31. Prismatic, columnar, massive, fibrous, granular and compact habits of jadeite were observed.

**Colour.**—Jadeite varies from pure white to various shades of green. Not infrequently green spots or streaks are observed in the white varieties. Other less common tints are amethystine, light-blue, bright-red, brownish and black. The bright-red and brownish tints are observed in a thin outer zone of jadeite boulders embedded in red earth, and the colour is due to the dissemination of ferruginous matter by percolating water. About one-third of an inch from the surface the red colour entirely disappears. Thin sections of red jadeite are seen to be stained red and yellow with haematite and limonite respectively.

**Microscopic Characters.**—Thin sections of jadeite are seen to consist of interlocking, hypidiomorphic, rather irregular prismatic sections. It is this interlocking arrangement of the crystals that makes the mineral so tough. Idiomorphic sections show the development of prisms commonly, and of pinacoids rarely. Sometimes the jadeite shows granoblastic structure, at others, it is mylonitised, and in places radially arranged, sheaf-like aggregates are to be seen. The average double prismatic cleavage angle is 87·3, while it varies from 85·2 to 89·0, depending upon the angle at which the crystal is lying in the section. Jadeite is normally colourless in thin sections, but the bright-green variety exhibits a pale-green colour under the microscope and is very slightly pleochroic. The birefringence is strong. The maximum extinction angle observed is 43·5° while the minimum is 27°. Undulose extinction is very characteristic, indicating that the mineral has undergone considerable strain. Inclusions of amphibole are not infrequent and occasionally those of albite too. The mineral becomes cloudy and opaque on account of meteoric weathering, but under the microscope it is also seen altered to colourless amphibole.

The new analyses 5, 2 and 3 yield the following chemical compositions, expressed in terms of silicate molecules.

| | (5) | (2) | (3) |
|---|---|---|---|
| $NaAl(SiO_3)_2$ | 83·78 | 77·40 | 64·80 |
| $NaFe(SiO_3)_2$ | 1·38 | — | 0·85 |
| $CaAl_2(SiO_3)_4$ | 11·86 | 10·65 | 20·00 |
| $MgAl_2(SiO_3)_4$ | — | 7·70 | — |
| $FeAl_2(SiO_3)_4$ | — | 4·30 | — |
| $MgSiO_3$ | 0·97 | — | 6·65 |
| $FeSiO_3$ | 1·43 | 0·78 | 4·80 |
| $CaSiO_3$ | 0·15 | — | 2·10 |

An examination of the analyses shows that the apple-green jadeite of Sietaung (3) has a peculiar composition due to its high content of calcium, iron, and magnesium metasilicates.

The mineral named " tawmawite " by Bleeck is characterised by its dark emerald-green colour, and by an exceedingly strong pleochroism, (emerald-green to lemon-yellow); Bleeck described it as a chromiferous epidote, and gave the following analysis :

| | |
|---|---|
| $SiO_2$ | 37·92 |
| $FeO$ | 9·93 |
| $Al_2O_3$ | 12·83 |
| $Cr_2O_3$ | 11·16 |
| $CaO$ | 25·35 |
| $H_2O$ | 2·38 |
| | 99·57 |

Recently Lacroix has questioned the existence of tawmawite and refers it to chromiferous jadeite which was analysed by M. J. Orcel with the following results :

| | |
|---|---|
| $SiO_2$ | 57·90 |
| $TiO_2$ | 0·23 |
| $Al_2O_3$ | 19·40 |
| $Cr_2O_3$ | 3·75 |
| $Fe_2O_3$ | 1·37 |
| $FeO$ | 0·06 |
| $MgO$ | 2·82 |
| $CaO$ | 0·75 |
| $Na_2O$ | 13·20 |
| $K_2O$ | 0·40 |
| $H_2O+$ | 0·60 |
| $H_2O-$ | 0·05 |
| | 100·53 |
| Density | 3·343 |

The following composition is to be deduced from these values:

| | |
|---|---|
| $NaAl(SiO_3)_2$ - - - | 74·35 |
| $NaFe(SiO_3)_2$ - - - | 3·95 |
| $NaCr(SiO_3)_2$ - - - | 11·26 |
| $MgAl_2(SiO_3)_4$ - - - | 1·50 |
| $CaSiO_3$ - - - - | 1·55 |
| $MgSiO_3$ - - - - | 6·70 |
| $FeSiO_2$ - - - - | 0·11 |
| | 99·42 |

The morphological characters, characteristic pleochroism, chemical composition and other optical properties of this mineral agree closely with those of tawmawite, and Lacroix has suggested that it seems prudent to abandon the term "tawmawite," and to name the mineral in question *chromojadeite.*

In the jadeitite an amphibole occurs in large laminae, of a greenish-brown to a blackish-green colour, reminding one of diallage. This is the *szechenyite* described by Krenner. Another amphibole is greenish, acicular, and similar to actinolite, but it is chemically like the preceding one. The following table gives Krenner's analysis (1), and that of the acicular variety (2) by J. Orcel.

| | (1) | (2) |
|---|---|---|
| $SiO_2$ - - - - - | 55·02 | 58·65 |
| $Al_2O_3$ - - - - - | 4·53 | 5·98 |
| $Fe_2O_3$ - - - - - | 1·04 | 2·37 |
| FeO - - - - - | 3·28 | 1·34 |
| MgO - - - - - | 20·36 | 18·56 |
| CaO - - - - - | 8·00 | 1·40 |
| $Na_2O$ - - - - - | 6·71 | 9·30 |
| $K_2O$ - - - - - | 1·52 | 1·10 |
| $H_2O$ - - - - - | 0·51 | 2·20 |
| | 100·97 | 100·90 |

It will be noticed that these amphiboles possess a special composition, and do not correspond either to glaucophane or to common hornblende, as has been generally believed.

The albitites are granulitic rocks composed almost exclusively of untwinned albite ; but, as in the case of the jadeitites, types containing amphibole and pyroxene also occur.

The chemical compositions of four different types (2-5) are quoted from Lacroix's account together with the theoretical composition of albite (1):

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| $SiO_2$ | 68·7 | 67·10 | 63·47 | 66·30 | 59·42 |
| $Al_2O_3$ | 19·5 | 20·42 | 20·76 | 19·94 | 10·81 |
| $Fe_2O_3$ | — | 0·23 | 1·27 | 0·19 | 1·28 |
| FeO | — | — | — | 0·43 | 2·58 |
| MnO | — | — | — | 0·07 | 0·17 |
| MgO | — | — | 1·11 | 0·22 | 10·69 |
| CaO | — | — | 1·16 | 0·72 | 4·30 |
| $Na_2O$ | 11·8 | 8·93 | 11·98 | 11·25 | 8·01 |
| $K_2O$ | — | 3·20 | 0·34 | 0·28 | 0·61 |
| $TiO_2$ | — | — | — | — | 0·40 |
| $P_2O_5$ | — | — | — | — | — |
| $H_2O+$ | — | — | 0·36 | 0·42 | 1·37 |
| $H_2O-$ | — | — | — | 0·21 | 0·13 |
| | 100·0 | 99·88 | 100·45 | 100·03 | 99·77 |
| Density | — | — | — | 2·671 | 2·91 |

1. Albite, theoretical composition.
2. Albitite, analyst, H. W. Foote.
3. Jadeitic-albitite, analyst, H. W. Foote.
4. Jadeitic-albitite, Tawmaw, analyst, M. Raoult.
5. Jadeitic and amphibolite-bearing albitite, Tawmaw, analyst, M. Raoult.

**The amphibolites.**—These rocks have proved very problematical as regards their origin, and they are not altogether happily named. The author has retained the name " amphibolites," which was applied to them by Lacroix, but they are not amphibolites in the commonly accepted sense, that is, regionally metamorphosed basic igneous rocks with a granulitic texture, as they are believed to consist of *primary* amphibole. On the other hand " hornblendite " would be equally inapplicable, on account of the unique composition of the amphibole of which they are composed. Further, they are of hybrid origin as explained in detail below.

Three varieties of these rocks may be recognised ; one is grey and composed of large twisted crystals and aggregates of amphibole ; the second type is coarser grained, it has a vaguely schistose appearance and contains a little jadeite in the typical specimens from the Kadon Mine. The third variety is the coarsest grained of the three and consists of a grey-blue amphibole mixed with emerald-green chrome-jadeite.

These amphibolites contain nodules of chrome-jadeite, they are often rich in chromite and show evidence of intense mechanical deformation.

The following is the composition of these szechenyite-bearing amphibolites, which constitute a lithological type quite unknown elsewhere.

1. Amphibolite, Kadon Mine, analyst, Raoult.
2. Amphibolite, Tawmaw, analyst, Raoult.
3. Amphibolite bearing chrome-jadeite, Tawmaw, analyst, Raoult.

| | (1) | (2) | (3) |
|---|---|---|---|
| $SiO_2$ | 56·18 | 55·82 | 57·52 |
| $Al_2O_3$ | 7·37 | 2·56 | 9·57 |
| $Fe_2O_3$ | 2·26 | 3·36 | 0·31 |
| FeO | 3·69 | 2·59 | 4·50 |
| MnO | 0·09 | 0·09 | 0·16 |
| MgO | 16·97 | 21·20 | 13·27 |
| CaO | 0·84 | 1·16 | 3·18 |
| $Na_2O$ | 9·18 | 9·12 | 8·83 |
| $K_2O$ | 0·72 | 0·53 | 0·51 |
| $TiO_2$ | tr. | — | 0·10 |
| $H_2O+$ | 2·41 | 3·21 | 1·71 |
| $H_2O-$ | 0·28 | 0·30 | 0·23 |
| $Cr_2O_3$ | — | — | — |
| | 99·99 | 99·94 | 99·89 |
| Density | 3·027 | 3·006 | 3·120–3·146 |

**The so-called chloritic zone.**—Bleeck described the peripherial zone as composed of chlorite (with chloritoid, actinolite and zoisite). The specimens, collected by the author from the Kadon Mine and described by Lacroix, have a different composition. One specimen is of a green colour, much crushed and folded, contains veinlets of calcite, and is composed of serpentinous minerals and broken needles of jadeite. The other is composed chiefly of fine needles of amphibole in a fine textured, irresolvable base.

The analyses below show marked differences between these rocks and those described by Bleeck, though they may occupy the same situation.

*A*. Serpentinised rock containing jadeite, Tawmaw.
*B*. Contact rock, Tawmaw.

| | (A) | (B) |
|---|---|---|
| $SiO_2$ | 41·50 | 47·52 |
| $Al_2O_3$ | 5·15 | 5·38 |
| $Fe_2O_3$ | 2·76 | 3·20 |
| FeO | 2·19 | 1·99 |
| MnO | 0·10 | 0·10 |
| MgO | 27·39 | 24·95 |
| CaO | 3·66 | 0·70 |
| $Na_2O$ | 3·59 | 5·76 |
| $K_2O$ | 0·63 | 0·79 |
| $TiO_2$ | — | — |
| $P_2O_5$ | — | — |
| $H_2O+$ | 8·89 | 6·86 |
| $H_2O-$ | 1·15 | 2·43 |
| $Cr_2O_3$ | 0·41 | 0·41 |
| $CO_2$ | 2·82 | — |
| | 100·24 | 100·09 |

**Origin of the jadeite-albite rocks.**—Rosenbusch [1] noticed that jadeite may have been formed by the addition of one molecule of albite to one of nepheline. Such a composition is comparable with that of a leucocratic nepheline-syenite, almost exclusively sodic. The density of jadeite is much greater than that of albite, therefore high pressure must have played its part in its formation.

Pirrson, Iddings[2] and Grubenmann[3] considered jadeitite to be an orthoschist, the last named referring the rock to the deepest zone of dynamo-metamorphism, the Tiefeste Zone, the corresponding rock type from intermediate depths being nepheline-gneiss (Mesoalkaligneiss).

Noetling and Bleeck agree in considering the whole of the Tawmaw sodic rocks as forming a dyke of eruptive origin. Bleeck, however, considers that, from the genetic point of view, the jadeitite and albitite must be separated from the amphibolite, the first two having been intruded into the latter, which he believes to be genetically related to the peridotites. In support of this view he stresses the occurrence of xenoliths of the amphibolite in the jadeite-albite rocks, the enclosures being aligned parallel to the margins of the dyke, while a " ribboned

[1] Rosenbusch, H., *Elemente der Gesteinlehre*, 1910, p. 647.
[2] Pirrson, L. V. and Iddings, J. P., *The Bishop Collection*, vol. i, 1906, p. 162.
[3] Grubenmann, U., *Die Kristallinen Schiefer*, 1910, p. 228.

texture" is frequently here developed. Bleeck explains the presence of chromite in both the peridotites and the jadeite-albite rocks as due to their close magmatic relationship, the serpentinised peridotites and the gabbro (in the course of being transformed into crystalline schists) being products of differentiation from the same body of magma, and this gave rise, as an end member of extreme composition, to a nepheline-aplite. This nepheline-aplite, instead of appearing in its original form, has been changed after intrusion into jadeite-albite rock, the change being in the nature of an exomorphic transformation effected by granite magma intruded under high pressure following tectonic activity.

Professor Lacroix thinks that the jadeite, albite and amphibolite are linked together in a different way from that suggested by Bleeck. It is important to note that the composition of the amphibolite is unique: its low content of lime and alumina will not allow one to regard it as derived by regional metamorphism from the gabbro. Further, it is very rich in magnesia and, like the white rocks of the dyke, is characterised by a high content of soda and low content of potash. Thus, in some respects it appears to be linked with the albite-jadeite rocks, and in others, with the peridotites.

Lacroix does not think that all the Tawmaw rocks can have been produced by the normal differentiation of a nepheline-rich magma on the following grounds: all the known examples of such magmas are characterised by the absence of chromite and low content of magnesia in the leucocratic rocks formed from them, while the mesocratic and melanocratic members, such as theralites, are rich in lime and iron as well as in magnesia. This contrasts strongly with the amphibolites of Tawmaw, the analyses of which in fact do not correspond with any other known rock. On the other hand, the peridotites into which the Tawmaw dyke was intruded are destitute of alkalies, and practically without lime; they consist essentially of magnesia and iron, and contain a little chromite. It is noteworthy that all the rocks of the dyke contain chromite, and Lacroix states that the green spots in the dyke rocks are indubitably due to chromite.

Lacroix claims that the dyke fissure was originally filled with a highly aluminous and richly sodic hololeucrocratic magma, which stoped its walls, the amphibolite representing endomorphosed portions of these. The amphibolite, on this view, is certainly not crystalline schist which has been metamorphised by the magma, but represents peridotite that has contributed magnesium, iron and chromium, while the magma has contributed soda and silica. Further, it is evident that to provide the requisite silica to effect the transformation, a more highly silicated magma than the nepheline-bearing type postulated by Bleeck, must have been involved. It seems reasonable to suppose that this magma had the composition of granite-aplite.

Bleeck pointed out that there is a narrow zone of chlorite-schist, bearing chloritoid and chrome-epidote, between the peridotite and the dyke rocks. This he regarded as part of the metamorphic aureole of the dyke. Lacroix states that no such rocks were found among those which he examined, and finds it difficult to understand how a purely sodic magma could, by interaction with peridotite essentially free from lime, give rise to lime-rich minerals such as zoisite, tawmawite and others. This point is referred to again below.

Lacroix regards as important corroborative evidence the fact that certain glaucophane-schists associated, according to Bleeck, with the chlorite-schists, and derived from the gabbro, are chemically entirely dissimilar from the amphibolite of Tawmaw. This is brought out by the analysis recorded below, which should be compared with the analysis of the amphibolite on p. 71.

| | |
|---|---|
| $SiO_2$ | 47·12 |
| $Al_2O_3$ | 12·45 |
| $Fe_2O_3$ | 7·14 |
| $FeO$ | 9·72 |
| $MnO$ | 0·21 |
| $MgO$ | 6·36 |
| $CaO$ | 6·92 |
| $Na_2O$ | 3·19 |
| $K_2O$ | 1·17 |
| $TiO_2$ | 2·70 |
| $P_2O_5$ | 0·09 |
| $H_2O+$ | 2·69 |
| $H_2O-$ | 0·22 |
| | 99·98 |

Glaucophane-schist with epidote, Burma (125–B), quoted from Lacroix, A. *op. cit.*

As noted above, Grubenmann regarded jadeitites as the end product of the conversion of nepheline-syenites, through nepheline-gneiss, into crystalline (jadeite-) schists. Lacroix points out, however, that he has described from Madagascar certain ortholeptynites (deep-seated types of Grubenmann) associated not with jadeitites, but with nepheline-gneisses; while at Tawmaw albitites and amphibolites, characteristic of Grubenmann's intermediate zone, are found side by side with jadeitite, in the same dyke.

It may be remarked that similar field relations have been described by A. L. Hall [1] from a South African locality, where granite-pegmatite traverses altered peridotites, highly magnesian like those of Tawmaw. The magma has here suffered extensive desilication, the pegmatites losing their quartz, but corundum, not jadeite, has been produced as a distinctive new mineral. Evidently the physical conditions and the actual composition of the magma involved were not identical with those at Tawmaw; but the example serves to prove that highly magnesian rocks are capable of causing desilication of acid magma with the complete disappearance of quartz and the development of undersaturated minerals.

Having discussed the views expressed by different petrologists on the origin of the jadeite-albite rocks of Burma, the author, who in the course of his official duties has studied the rocks in the field, is able to confirm the main conclusions arrived at, on theoretical grounds, by Professor Lacroix. There is no shadow of doubt that the jadeite-albite rocks are intrusive into the serpentinised peridotites of the district, either in the form of dykes, as has been commonly supposed, or more probably in the form of sills, as is evidenced by the numerous sections examined by the author.

With regard to their mode of origin, they are evidently products of interaction between a magma that was notably rich in soda, but deficient in lime, magnesia and iron, and the wall-rock, which was serpentinised peridotite. As a direct consequence of this reaction the rocks and minerals of the contact zone, which also occur as inclusions in the jadeite-albite complex, were formed. These comprise chlorite-schist, amphiboles,

[1] A. L. Hall, *Trans. Geol. Soc. South Africa*, vol. 25, 1922, p. 43.

chrome-epidote and chrome-garnet, the relationships of which have been explained in the account of the Tawmaw sheet. It may be remarked that both Bleeck and Lacroix were misled by the small number of specimens available, and these came from one locality (Tawmaw) only; the author has had the great advantage of examining very many outcrops of these rocks, and his main conclusions have been incorporated in the reports of the Director of the Geological Survey of India, as noted in the above account. It will be seen from the foregoing discussion that Lacroix found it difficult to account for the presence of the lime-bearing minerals occurring at the contact and as inclusions in the main intrusive mass. Consequently he was inclined to question the existence of "tawmawite" or chrome-epidote, as described by Bleeck. There is, however, no doubt that "tawmawite" does occur in the contact rocks at a number of different localities, usually associated with the chrome-garnet, uvarovite, particularly from Maw-sit-sit. This fact has not been previously recorded.

The explanation is undoubtedly to be found in the fact that not only dunites, which are of course lime-free, but also other types of peridotites, including diallage-bearing varieties, are present in the ultrabasic complex, and these are adequate to supply the lime necessary for the formation of these minerals.

The author believes that the immediate parent of the albite-jadeite rocks was a soda-granite-aplite produced as a normal product of differentiation from the granite magma represented in the district by the types enumerated above. The complete assemblage of igneous rocks in the district comprises peridotites of several types, gabbros of several kinds, locally represented by glaucophane-schist, by amphibolites, epidiorites, etc., and granites of several types, including pegmatites and aplites, the latter consisting of albite and quartz. The author agrees with Lacroix that the jadeite-albite rocks were derived from the magma represented by these aplites. The aplitic magma, a residuum from the granite magma, on coming into contact with the ultrabasic wall-rock suffered desilication, with the consequent elimination of the quartz and the conversion of much of the potential albite into jadeite. The silica released from the magma was used up in converting the orthosilicates of the peridotites into metasilicates, within the contact zone, which, as noted above, is characterised by soda-rich, but lime-poor, amphibole. It is important to note that the desilication is only partial, as the rocks still contain large quantities of albite, with only *some* jadeite. The latter is sometimes closely associated with albite in albite-jadeite rock; but in other cases it forms lenses of nearly or quite pure jadeite-rock, embedded in equally pure albite rock. The amount of jadeite present appears to be directly proportional to the quantity of albite. The distribution of the two minerals suggests imperfect separation, and it may well be that, on account of the superior specific gravity of jadeite (3·33 as compared with 2·6 for albite), it tended to separate under gravity control. Segregation and sinking of the jadeite would be impeded, however, by the high viscosity of the desilicated magma.

It has to be understood that these reactions took place under almost unique conditions, presumably involving very high pressure, under which conditions nepheline proved unstable. It is well known that albite and nepheline are associated in a number of types of elaeolite-syenite, and in all proportions; but the jadeite-albite association is extremely rare. The nepheline is usually accounted for by desilication of the albite molecule: but as jadeite is intermediate between these two extremes of composition, it would be reasonable to suppose that a limited degree of desilication would result in the formation of the intermediate compound, jadeite. But that is not the case except in very rare instances, as at Tawmaw. Although he postulates high pressure as the controlling factor, the author would emphasize that this was operative *during*, and not after the consolidation of the rock; he is not at all in favour of the hypothesis, favoured by Bleeck and Rosenbusch, to the effect that the jadeite has been formed by the dynamo-metamorphic compression of one molecule of albite with one of nepheline to form two of jadeite. Lacroix also does not favour such an hypothesis.

## JADEITE TRADE.

Every piece of jadeite found has to be valued and the owner has to pay a commission of 5 per cent. to the valuation committee in the jade mines. As a rule the valuations in the mines are very low. If the financier elects to keep the stone (which he generally does), he has to pay half of the value of the stone to the coolies or workmen after paying the *Mahumanta* tax of 10 per cent. to the Duwa in whose jurisdiction the stone is found, if it is valued at Rs. 100/- or more.

It is noteworthy that in sales and valuations prices are not mentioned openly, but are indicated by a conventional system of finger pressures under cover of a handkerchief.

The stone is then taken away to Mogaung, either by coolies or on mules, after paying the necessary local tolls. If a boulder is very heavy then the coolie transport from the mines to Nanyaseik is very costly. For instance, about fifty coolies or more have to be engaged to transport a boulder weighing about a ton; these proceed by very short stages and in all it may cost about Rs. 1,000/-. Beyond Nanyaseik it may be taken by bullock carts to Mogaung, or it may be sent by river on bamboo rafts from Kamaing.

The stone can only be taken out of Mogaung after paying an *ad valorem* royalty of 33 per cent. to the Government Jade license.

Much dealing in jade goes on in the mines and at Mogaung amongst Burmese, Chinese and other traders; but it is entirely speculation, because usually the stones are not cut until after the Government royalty has been paid on them, and therefore their real value is merely guess-work. I may quote here from a manuscript note by Major F. L. Roberts, formerly Deputy Commissioner, Myitkyina. "From the time jade is won in the Jade Mines area until it leaves Mogaung in the rough for cutting there is much that is underhand, tortuous and complicated, and much unprofitable antagonism. In my opinion the whole business requires cleansing, straightening and the light of the day thrown on it."

**Shipping.**—Boulders of jadeite are wrapped in gunny bags, tied with hemp rope and then shipped from Rangoon, in a

Chinese boat to Hong Kong, Canton, Shanghai, etc. A considerable quantity of stone is smuggled across the border, in addition to the small amount officially carried over by mules, which return from Burma to Yunnan and China with the advent of the rainy season.

**Buyers of Jadeite.**—No definite statistics regarding the purchasers of jadeite are available. However an aged, experienced dealer informed me that only about 25 per cent. of the jadeite is consumed in Burma. The remaining 75 per cent. is sent to China and Japan, and of this a small percentage eventually finds its way to America and Europe. The Chinese Government buy a considerable quantity of jadeite for making altars, sacred vessels, flower basins, etc. The Chinese believe that the wearing of jade prevents " evil eye," disease, or in other words acts as a charm. Jadeite jewellery finds great favour with the Chinese and Japanese ladies.

**Centres of Jadeite trade.**—A large number of the Chinese jade merchants make their purchases at Mogaung, but a fair number of Chinese merchants come up to the jade mines and are to be seen buying the mineral at Hpakan, Hwehka and other mining centres. Mandalay being the centre of cutting, commands the largest market for jade jewellery.

**Varieties of Jadeite.**—The local merchants recognise a number of varieties, depending upon their colour, translucency and texture.

(1) *Mya Yay* or *Yay Kyauk*, translucent and a uniform grass-green in colour. This is the most precious variety.

(2) *Shwelu.*—This is the light-green jadeite with bright-green spots and streaks. This is next to (1) in value. Both these varieties are used for expensive jewellery such as rings, necklaces, pendants, ear-rings, brooches, etc.

(3) *Lat Yay*, clouded jadeite, is used in making bracelets, buttons, hatpins, ornaments, drinking cups, etc.

(4) *Hmaw Sit Sit*, a dark-green variety, is rather soft and brittle, and is used in the manufacture of cheaper jewellery.

(5) *Konpi*, the red or brownish variety, is only found in boulders, embedded in red earth. This variety is not found at Tawmaw.

(6) *Kyauk-atha*, white translucent jadeite, is used for brace-

lets, stems of pipes, plates, spoons, flower-pots, cups, saucers, etc.

(7) *Pan-tha* (*Pan* in Burmese means flower, and *atha* means flesh, but it here denotes the translucent white jadeite). This variety is brilliant white in colour, and translucent, but opaque to a certain extent. This opacity is considered to be a defect and considerably reduces the price of the find. Like marble, it is used purely for decorative purposes, such as inlaying tables, chairs, boxes, and furniture generally.

(8) *Kyauk Amè*, the black variety. It is used for making buttons, bars for brooches, etc. This is the variety chloromelanite and is characterised by containing a large percentage of iron, replacing in part its aluminium. As the name implies, it is of dark-green colour often appearing quite black, except in thinnest splinters, when it is seen to be of a slightly translucent blackish-green colour.

## Jade-cutting Industry.

The methods employed in the cutting of jadeite and described below are really Chinese, and artistic carving is still mostly done in China. Surface carving and bead-making can be done in Mandalay.

**Abrasives.**—Two kinds of abrasives are used in the cutting of jadeite. For big boulders coarse carborundum is employed, while the finer grade is used in disc-cutting described below. Crushed gem sand from Mogok is also employed in grinding and polishing.

About 20 years ago a basket of the gem sand from Mogok (sand weighing about 200 lb.) could be bought for a rupee (one shilling and six pence); but at present the price varies from Rs. 7/- to 15/- depending upon the usual question of supply and demand. Before the sand is crushed into grinding powder, the gems of better quality are picked out to be used as jewels in watches. Most are exported to Europe, but some are employed locally in the manufacture of cheap jewellery.

**Local Preparation of Abrasives.**—The pounding and pulverising of the sand is effected by a simple contrivance. A heavy weight is tied by means of a string strung to a bow fastened on to the ceiling of the house. Generally this task is entrusted to