A VISIT TO THE GEM DISTRICTS OF CEYLON AND BURMA

BY

FRANK D. ADAMS

Emeritus, Vice Principal, Dean of the Faculties of Applied Science and Graduate Studies, and Logan Professor of Geology at McGill University, Montreal, Quebec

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FROM THE SMITHSONIAN REPORT FOR 1926, PAGES 297–318
(WITH 6 PLATES)

(PUBLICATION 2891)

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[With 6 plates]

CEYLON

The island of Ceylon, which is one of the most beautiful possessions of the British Empire, has been an abode of man from the very earliest times. The Veddhas, a wild tribe of some 4,500 people still living in the fastnesses of the jungle in the east central portion of the island, are believed to represent a remnant of the oldest inhabitants of which we have any actual knowledge, but in the caves in which they live there are found the stone axes and other implements of Paleolithic people who represent the first race of men who inhabited our globe, and of whom they may be, for all that is known, the direct descendants. About the fifth century before Christ there came the Aryan invaders, apparently from the north of India, who drove the Veddhas into the remote fastnesses of the jungle and developed the remarkable Singhalese civilization, whose high character is demonstrated by the remarkable and very extensive system of irrigation works which they built up and through which they made the island wonderfully productive. Great cities arose, some of which are believed to have had a population of over a million souls and whose temples and public buildings show that the people were accomplished architects and sculptors. About the third century before Christ there began a series of waves of invasion by the Tamil people of the south of India, who defeated and drove the Singhalese down into the southern half of the island, completely destroying the great irrigation system and throwing down the cities. They "let in the jungle," which, slowly advancing as the years went by, resumed its ancient domain and completely covered up the former glorious abodes of men. The "buried cities" of Anaradhapura, Pollonnaruva, and Siguri, whose remains can be seen in the midst of the jungle, constitute one of the most striking examples of an obliterated civilization. Occasional travelers from Greece and

[1] Reprinted by permission from Transactions of the Canadian Institute of Mining and Metallurgy, part of Vol. XXIX, 1926.

Rome penetrated to these far eastern lands and called the island Taprobane, the name employed by Milton for "India's furthest isle"—and later, in A. D. 1507, came the Portuguese and took possession of the country, only to be dispossessed in A. D. 1656 by the Dutch, who in their turn gave place to the British in A. D. 1796. The latter, however, were the only people who ever penetrated to the interior and took possession of the whole island, which they did in A. D. 1815.

Ceylon has an area of 25,332 square miles, and is thus about five-sixths the size of Ireland, and now has a population of 4,500,000, consisting chiefly of Singhalese, Tamils, "Moormen" (the descendants of ancient Arab traders, of whom Sinbad the Sailor was one), Burgers (the descendants of the Dutch people), and the English. The island supplies its own food and exports tea, rubber, and the products of the coconut. The people are prosperous and contented and have representative government under a governor appointed by the Crown.

The periphery of the island consists of a plain only a few feet above sea level, narrow in the south but much wider in the north, and which marks a comparatively recent and very moderate elevation of the island above sea level. From this coastal plain the central and southern portions of the island rise rapidly into higher land, culminating in mountain peaks, of which the most celebrated, though not quite the highest, is Adam's Peak (7,353 feet).

The higher portion of the island is composed exclusively of very ancient Archean rocks, closely resembling those of certain parts of the Laurentian area of North America and probably of the same age.

There is no evidence that this area of ancient rock has ever been under water. It is believed to owe its present form to the long-continued processes of subaerial decay acting through the almost endless ages of geological time. This decay is still continuing everywhere. The rocks over large parts of this interior portion of the island are thus mantled with reddish residual clay, which forms the fertile soil of the rubber and tea plantations, clothing the steep slope of these ancient hills, and which is washed down into the river valleys, forming alluvial flats and discoloring deeply the waters of all the streams and rivers which flow through them. This clay in some places is replaced by a relatively hard, red laterite or lateritelike material, which, while soft enough to be very readily worked, shows a marked resistance to the action of the weather and is very generally employed for building houses.

While this decay is often deep-seated, it is remarkable to observe the very rapid transition from the completely decomposed rock represented by the red clay to the perfectly fresh rock, the two

frequently being separated by a transitional layer only a few tenths of an inch thick. Thus the clay when washed away by the tropical rains or cut through in road making lays bare surfaces of clean fresh gneiss, which under the microscope is seen to show no traces of alteration. It is thus possible to see good exposures of the underlying rock, at intervals at least, in almost all parts of this Archean area.

The heavy rainfall on the island runs off these high lands in a system of streams coming together into small rivers. These occupy deep V-shaped valleys whose course is usually determined by the strike of the gneissic rock, but in some cases follows the direction of joint planes or lines of faulting which cross the strike of the rock at right angles. The bottoms of these valleys are occupied by heavy alluvial deposits laid down by their respective streams, and it is in these alluvial deposits that the gems are found.

The gems have, of course, in all cases been derived primarily from the ancient Archean rocks which underlie the whole country, but they are seldom found in these rocks. John Davy, M. D.,[2] who visited the island in 1818, in a letter to his brother, Sir Humphrey Davy, written in that year, says, "I have ascertained that the native rock of the sapphire, ruby, cats-eye, and the different varieties of zircon is gneiss. These minerals and cinnamon stone occur embedded in this rock." A. R. Coomaraswamy, however, who for a number of years was Government mineralogist of Ceylon and is one of the most trustworthy writers on the mineralogy and geology of the island, in a paper written some years ago says that most of the interesting gems of Ceylon have not as yet been found in their original matrix.

J. S. Coates, Esq., B. A., the present Government mineralogist, in whose company the writer had the pleasure of visiting the gem workings in the Ratnapura district, informed him that he believes the various forms of corundum (sapphire, etc.) originate in quartz-free pegmatites cutting the gneissic series. If such proves to be the case, the occurrence is essentially identical with that of the corundum in the Bancroft district of Ontario.[3] The beryls (aquamarines) the writer has himself seen in quartz pegmatites, and Mr. Coates states that the zircons have their origin in the same rock. In Burma the rubies undoubtedly originated in the limestone bands of the gneissic series. Davy's statement may have been based on some information given to him by the natives, or by the term "gneiss" he may and probably did mean the gneissic series as a whole.

[2] Journal of Science and the Arts, Vol. V, 1818, p. 233.

[3] Adams and Barlow, Geology of the Haliburton and Bancroft Areas, Province of Ontario, Memoir 6, Geological Survey of Canada, 1910, p. 327.

The gems then have their origin in the ancient Archean rocks, but in just which members of the series they took their birth is not as yet known with certainty, except in the case of a few species.

While gems are found in many parts of the area, it is the streams flowing through the Balangoda, Rackwana, and Ratnapura districts that afford the chief supplies of precious stones. These three districts lie near one another in a relatively small area in the central part of southern Ceylon, halfway between the city of Kandy and the southern shore of the island.

The Ratnapura district is of especial interest, and much attention has been directed to it in recent years. Ratnapura signifies in Singhalese "City of Gems," and the little town which gives its name to the district is situated in the midst of the most exquisite scenery in Ceylon. It lies in a wide depression surrounded by hills 800 to 3,000 feet in height, the whole clothed with wonderfully beautiful, intensely green tropical vegetation. The finest views of Adam's Peak are obtained from here, and the outlines of the hills and mountains, resulting from age-long secular decay acting on the folded and jointed system of ancient gneisses, gives the hills and mountains sharper outlines than those presented by the rocks of corresponding age in our glaciated regions of the northern world. The slopes when not washed bare, as they are in places, are mantled with red residual soil or "cabok." Apart from its tropical features, the landscape must present a picture similar to that which was displayed by the Laurentian Plateau of Canada in pre-glacial times. Everywhere along the bottomlands which border the streams and little rivers flowing through the Ratnapura Valley are paddy fields, the fertile mud yielding under native cultivation rich crops of rice.

Much attention has recently been directed to the gem fields at Palmadulla, about 12 miles in a southwesterly direction from the town of Ratnapura, on account of a remarkable "find" made there a couple of years ago, sapphires and other gems to a value of some 9 lakhs of rupees ($297,000) having been taken from an area of between 3 and 4 acres in extent in a certain paddy field. These included some very large fragments of excellent blue sapphire 1 and 2 pounds in weight, as well as fine yellow sapphires and other less valuable stones. (Pl. 2.)

The Palmadulla workings are situated in a large stretch of paddy field in the bottom of the valley here, which has been cultivated for rice over a period of perhaps 1,000 years. The paddy field is underlain by clay, which is from 10 to 20 feet thick. Immediately beneath this there is a bed or layer of gravel called by the Singhalese "illam," which is usually thin and which in its turn rests on the decomposing surface of the country rock. The gems, if present, as is the case in all the Ceylonese gem deposits, are found in the illam, which thus

occupies a position identical with that of the gold gravels in many alluvial gold regions.

The searching for gems is a highly speculative operation and is usually carried out by a group of native workmen on shares. The owner of the paddy field gets one-fifth of any profits, the man who finances the operation another fifth, the remainder going to the men who carry out the actual work. After selecting a likely spot to sink a pit, the ground is tested from time to time as the work proceeds by driving down into it a long steel bar sharpened and tempered at the point. By pushing this down and twisting it around an experienced operator can tell on examining the bar after withdrawal at what depth below the surface the illam occurs, its thickness, and probable character. When the point of the rod passes through the illam and strikes the underlying decomposed bedrock, which looks like French chalk, the clay will be found adhering to its point, and if the surface of the rod is scratched this would indicate the presence of quartz or corundum pebbles or fragments in the gravel.

To get the illam out it is necessary to sink a small shaft or pit. In order to prevent the mud from flowing down into the pit, the latter is lined by a series of vertical poles driven down into the mud, behind which are laid branches of trees, sticks, or palm leaves. A man, sometimes with an assistant, works at the bottom of the pit shoveling the clay into a small bamboo basket, which, when filled, he throws deftly upwards and is caught by a man at the surface, who empties out its contents, then throws the basket down into the shaft again. When the pit gets deeper a third man sits on a transverse pole placed across the shaft from side to side and catches the basket thrown up by the man at the bottom of the shaft and in his turn throws it up over his head to the man at the surface. In this way all the clay is taken out and the shaft is sunk to the illam. This in its turn is then brought to the surface and is placed by itself on a clean, flat piece of ground prepared to receive it. The men engaged in these operations wear no clothes except a loin cloth and carry on an animated and evidently humorous conversation with one another, giving the whole operation the appearance of a pleasing pastime. If the weather is hot a rude shed, roughly thatched, is built over the opening of the shaft to give shade to the workers.

As the paddy field is usually wet, it becomes necessary to keep the pit free from water, which is done by bailing it out by means of an old kerosene oil can attached by a rope to a long pole balanced between two upright members, the whole resembling the device used for raising water from wells in many parts of French Canada. (Pl. 1.) It may be mentioned in passing that the kerosene can is employed throughout the Far East for a most amazing variety of purposes and affords a humble but convincing evidence of the widespread

peaceful penetration of the most remote eastern lands by western influences.

When all the illam in the pit has been brought to the surface the miners proceed to wash it. This is carried out, if possible, in one of the streams running through the area. The writer was fortunate enough when at Palmadulla to find a party engaged in washing illam and to join them in this, the most exciting part of the game. A few stakes had been driven down into the bed of a small rapidly flowing stream and some branches of trees laid across them so as to partially dam back the water at the place where they desired to wash, thus giving a greater depth of water Four or five Singhalese men, naked except for their waist cloth, were lined up across the stream in the water, which was some 3 feet deep; each was provided with a shallow basket closely woven of strips of split bamboo. The baskets are circular and measure about 2½ feet across at the top, the sides sloping down in a parabolic outline to the bottom point, somewhat similar in shape to the pans used in Brazil for washing alluvial gold. Other men brought down to the workers in small baskets the illam, which is then washed in the same manner as alluvial gold. The washing, however, is not carried as far as in the case of gold, the object being to wash away all the mud and leave the gravel behind in the basket. When this is done the basket is brought to the shore. When half a dozen of these baskets, containing the washed gravel are ready, another man, expert in the recognition of gems, takes the baskets and examines them carefully in succession. The basket is tilted up so that the sun shines upon the gravel which it contains, the man squatting down in front of it places his hands together, raises them in the rapid invocation of the "powers" to give him good luck, and, with rapid circular motion, goes over the gravel with his right hand, sweeping the surface layer down toward him into the side of the basket next to him. This process is continued until all the gravel has been sorted over. Squatting down beside the operator the whole process was clearly seen. The large gems, if any, are met with first in the coarse gravel near the top of the mass. By keeping a sharp lookout, any gem present can be detected by its color and transparency. In the six baskets which we examined there were three fragments of sapphires of good size; one of them was of fairly good color and would yield, when cut, a stone of commercial value, the other two had little or no commercial value. As these were found they were at once handed to the man who acted as the banker of the little group working this claim, and who carefully watched the proceedings to be certain that no gem which was found was secreted. As the sweeping process continued the gravel became finer and finer in grain and at one stage showed a red color due to the presence of a large number of minute red garnets. When

the whole contents had been worked over, the basket was passed to another man who reexamined its contents with greatest care in order to pick out any minute particles of gems which might still remain in the gravel and which might bring some small return. When all the illam was washed the gems found would be taken to Colombo and sold and the proceeds divided pro rata among the partners in the claim.

The location of the pits often seems to have been selected in a haphazard manner, although frequently the attempt is made to locate them in what is conjectured to be the course of the old stream which originally meandered through the valley.

Visitors coming to the district from abroad often think the gemming could be carried on much more efficiently and to great advantage by employing large modern dredging plants. The chief reason why this can not be done is that it is very difficult to secure titles to any extended piece of territory. The paddy fields are held in small areas by different owners, who, as a general rule, have many mortgages and liens on their lands—often of the most complicated character—so that it is practically impossible to secure a clear title, free from encumbrances, to an area sufficiently large to operate a dredge.

The following precious and semiprecious stones are found in Ceylon: Amethyst, aquamarine, chrysoberyl (and its varieties, alexandrite, and cat's-eye), garnet, moonstone, peridote, ruby, sapphire, spinel, topaz, tourmaline, and zircon. They are all found in the alluvial deposits just described, but the moonstone (a clear chatoyant variety of orthoclase feldspar) is more generally obtained from pegmatites and other quartz-feldspar rocks which are found in situ.

Ruby and sapphire have the same composition, being clear, transparent varieties of corundum, the former red and the latter blue in color. Some stones show a peculiar blending of the red and blue colors, the latter preponderating, and are known as "oriental amethyst." While the true sapphire is blue, yellow sapphires (called sometimes "oriental topaz") and white sapphires are frequently found as well. Diamonds, emeralds, opals, and turquoise are not found in Ceylon.

Much has yet to be learned concerning the details of the processes by which the gem stones have been transported and concentrated in the gravels in which they are now found. Of the gems washed from the same deposit some are found to have suffered but little rounding of the crystal edges through attrition, while others are so much rounded that no traces of the original crystal form remain. This is true even of exceedingly hard gems, such as sapphires, and would seem to indicate that while some of the stones have been moved but a short distance from the veins (?) in the bedrock whence they are derived, others must have been carried a very considerable distance

under conditions of intense mechanical wear. The thick deposits of alluvial and residual clays which mantle the underlying rock in the lowlands, where the gems are found, have made it impossible as yet to read all the details of the history of the processes by which these precious stones have been assembled where we now find them.

While it is impossible to obtain accurate statistics with reference to the value of the annual output of gems in Ceylon—the work being carried on by little bands of men working here and there all over the gem-bearing districts and continually changing their scene of operations—J. S. Coates, Esq., B. A., the government mineralogist of Ceylon, informed the writer that it amounts to between 8 and 10 lakhs of rupees—that is to say, between $264,000 and $330,000 annually.

As is well known, the gem trade has in the last few years been much disturbed by the fact that it has been found possible to make artificial "synthetic" rubies and sapphires of the various colors displayed by the natural stones, as well as certain other gems hitherto to be obtained only from the rocks or gravels of the earth's surface. Furthermore, these artificial stones are not mere imitations of the true gems—they are actual crystals of ruby, sapphire, etc., identical in composition and all physical properties with the latter. They are true gems made in the laboratory of man, instead of in the laboratory of nature, and can be distinguished from the natural stone only by the most expert examination—if at all. This fact shows how dangerous it is to prophesy what science will or will not be able to do as time goes on. One of the best-known books on Ceylon, entitled "Ceylon, by an Officer of the Late Ceylon Rifles, 1876," contains the following passage: "We can take life, but we can not restore it; we can reduce a costly and brilliant gem to a worthless powder, but we can not turn the powder into a gem; nature has hitherto defied the cleverest savant and will continue to do so until the end of time." Artificial stones are built up or grown by heating, by means of a powerful blowpipe, a fine powder having the composition of the gem it is desired to produce, and the powder under these conditions of great heat grows into an actual crystal.

BURMA

Burma is now administered as a Province of India. It is bounded on the west by Bengal, Assam, and the feudatory State of Manipur, on the east by Siam, and on the north by Thibet and China.

The dominant physiographic feature of Burma is the Irrawaddy River, running from north to south through a valley with low banks. The river rises in the mountains of the far north, one tributary branch coming from Thibet. The head of navigation for river boats is at Bhamo, which is situated about 25 miles from the Chinese bor-

der, and the river is thence navigable to the sea, a distance of over 900 miles. It is a rapidly flowing stream, running most of the way in long meanders between low banks, but about Prome it commences to divide up into a number of branches, which find their way to the sea in a series of devious courses through the very fertile and highly cultivated delta of the Irrawaddy. A flotilla of no less than 550 shallow-draft steamboats, belonging to the Irrawaddy Flotilla Co., run regularly up and down the river, and pushing into every nook and corner of the delta constitute the main transportation system of the country.

Bordering the river on either side is a wide tract of flat land with ranges of hills running north and south. These physiographic elements constitute the land of Burma.

Burma is rather more than ten times the size of Ceylon, having an area of 262,000 square miles and a population (including that of the Shan States) of 13,212,000 persons.

As in the case of Ceylon, the Portuguese were the first Europeans to settle in Burma, which they did in A. D. 1519, to be followed less than 100 years later by the Dutch, and soon after this by the English. About the middle of the seventeenth century all European merchants were expelled from the country, owing to a dispute between the Burmese governor of Pegu and the Dutch. The Dutch never returned; the English were subsequently invited to return to Burma, which they did. The Government of Burma in the following years passed from one ruler to another and the English settlements were attacked from time to time, which led in succession to the first, second, and third Burmese wars and eventually to the annexation of the whole country to the British Dominions in A. D. 1886.

Burma now has representative government, and the country, being freed from the tyranny of oppression, exercised by its successive rulers in former times, enjoys a higher degree of freedom and prosperity than it has ever known in times past. The Burmese as a race are short in stature and thick-set. The men wear long hair on their heads, but have little or none on their faces, and show in their features a strong infusion of Chinese blood. They are well clad; both men and women wear skirts and both delight in bright colors and silk attire. There is probably no country in the world which presents in its streets and market places such a wonderful display of bright, harmonious color. In many respects Burma presents a striking and pleasing contrast to India. The merry, brightly clothed Burmese have no counterpart in Hindustan, and the richness of the soil and exuberance of the vegetation, together with the sleekness and vigor of the cattle, is at once marked by a visitor coming from India. The life of the Burmese is free from the deadening effects of castes and the seclusion of women, two customs which stereotype the existence

of so large a part of the inhabitants of India. The country back from the Irrawaddy, in northern Burma, in the Shan States and westward toward the Arakan hills, is inhabited by various less-civilized peoples, each with its own peculiar dress and appearance, who come down to the river in picturesque groups to buy and sell when the market boats pass up and down on their regular sailing schedule.

The country is rich in minerals. The great silver-zinc-lead deposits at the Bawdwin mines have been worked from the most remote antiquity. Tin and tungsten are of widespread occurrence in southern Burma. Coal occurs in many parts of the country, and the oil fields are large and highly productive. The greater part of the jade carved in China really comes from the Myitkynia district of Burma, where there are also large amber deposits.

As will be seen in the accompanying sketch map (fig. 1) showing the main features of the geology of Burma, a long and generally narrow band of very ancient pre-Cambrian (Archean) rocks, having approximately a north-and-south direction, forms a protaxis running through the entire length of the country, passing across the border into China, and probably finding its farther continuation in one or the other of the narrow bands of Archean rocks shown in western Yunnan on the geological maps of southern China. This belt, coming up from Tenasserin, broadens out to the north of Mandalay and underlies the celebrated gem area of Mogok.

This district is reached by taking one of the Irrawaddy River boats at Mandalay (pl. 2) and ascending the river where picturesque groups of native people await the arrival of the boat at every landing place (pl. 3). At Thabeikkyin, a point about 70 miles above Mandalay, a good motor road runs back from the river in an easterly direction for a distance of 60 miles to the little town of Mogok, near the border of the northern Shan States. This road starting from Thabeikkyin, which is 600 feet above sea level, rises at first slowly and then passes through a group of mountain ranges over a pass 5,000 feet high (pl. 4) and descends to the Mogok Valley, which has an elevation of 4,000 feet. The higher portions of this road afford a view in all directions over a veritable sea of mountains clothed with a luxuriant forest in which are magnificent flowering trees and many birds, the scene being one of extraordinary beauty. Much of this forest has been set aside for Government forest reserves.

The isolated hill at Mandalay (954 feet), which rises abruptly from the plain on which the city is situated, is composed of a white crystalline limestone, rendered impure through the presence of grains of pyroxene, biotite, graphite, etc. It is identical in appear-

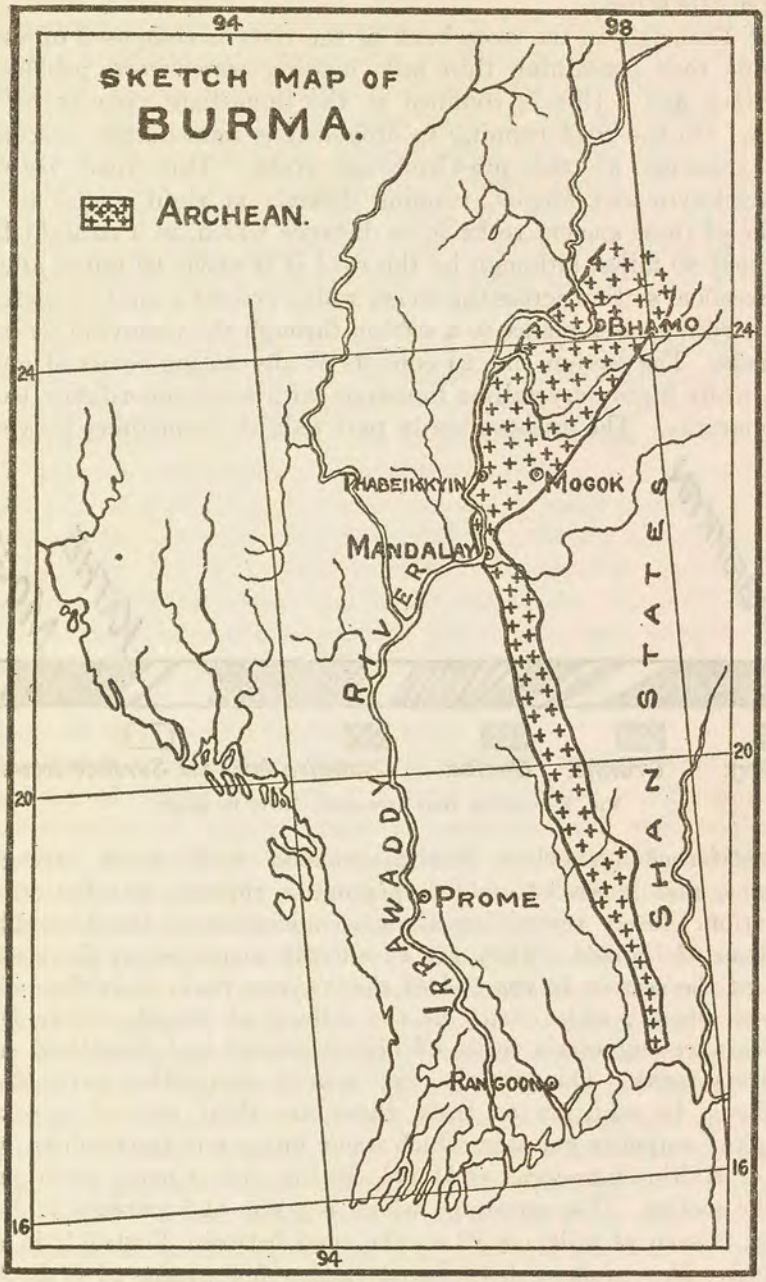
94
98
SKETCH MAP OF
BURMA.
ARCHEAN.
BHAMO
24
24
PHABEIKKYIN
MOGOK
MANDALAY
RIVER
IRRAWADDY
SHAN STATES
20
20
PROME
RANGOON
16
16
94

FIG. 1

ance with the crystalline limestones of the Laurentian of Canada (Grenville series).

At Thabeikkyin the steep bank of the river is composed of a soft friable rock containing thin beds holding water-worn pebbles of Tertiary age. This is confined to the immediate vicinity of the river. On the road running to Mogok it is immediately succeeded by exposures of the pre-Cambrian rocks. This road between Thabeikkyin and Mogok, running directly at right angles to the strike of these ancient rocks for a distance which, in a straight line, is about 40 miles, although by the road it is about 60 miles, affords an excellent section across the series, which present a most remarkable and striking resemblance to a section through the Grenville series in Canada. The section (fig. 2) consists of alternating bands of gneiss and white highly-crystalline limestone with some subordinate bands of quartzite. The gneisses are in part reddish (sometimes grayish),

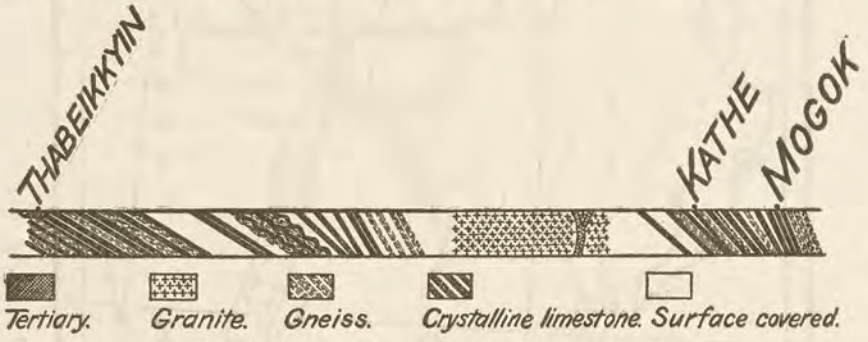

FIG. 2.—Section from Irrawaddy River to Mogok

garnetiferous orthoclase biotite gneisses, with many stringers, streaks, and lenses of reddish pegmatite running parallel to the foliation, closely resembling those so abundant in the Laurentian Plateau of Canada. They are excellently displayed at the eastern end of the section in the bed of the Yaynee River near the power house, about 2 miles south of the village of Mogok, where their appearance suggests a series of highly altered and granitized sedimentary rocks. They are also well seen in many other parts of the section. In addition to these there are light colored pyroxene (augite) scapolite gneisses, which occur intimately interbedded with the crystalline limestones at Mogok, Kathe, and at many other parts of the section. The quartzite, which is white and vitreous in character, is seen at milepost 22 on the road between Thabeikkyin and Mogok. It contains a little biotite and a few grains of orthoclase scattered through it and bears a striking resemblance to certain quartzites in the Grenville areas of Canada. There are large exposures of graphitic quartzite about 18 miles from the former station.

The limestones, which occur in very thick bands over wide areas are white and highly crystalline. Some bands are nearly pure, others contain little grains of biotite-pyroxene, graphite, and other accessory minerals marking the lines of bedding, and they are again identical in appearance with those of the Grenville series in Canada. These limestones are in some cases more or less magnesian. The metamorphism to which the whole district has been subjected was very intense and the limestones are in many places very coarsely crystalline. As mentioned, the rubies for which this district is renowned have these limestones as their original matrix and are more abundant in the coarser grained than in the finer grained varieties.

At one place between Mogok and Sinkwa (on the road to Thabeikkyin) there occurs by the roadside, closely associated with the limestone, a most interesting occurrence of a nepheline rock of the variety known as urtite. It is a rather coarse-grained rock, dark in color, and showing an indistinct banding, and is composed essentially of greenish-yellow elaeolite and a black aegerine-augite. It also contains a considerable amount of primary calcite and resembles very closely certain varieties of nepheline rocks found associated with the Laurentian limestones of the Bancroft district of Ontario. Under the microscope the rock is seen to contain as accessory constituents a grayish-brown sphene in rather large grains inclosed in both the augite and the nepheline, as well as a little microcline, apatite, and black iron ore.

The extent and detailed geological relations of this unusual rock could not be determined, but it is very interesting as affording another instance of the association of nepheline rock with bodies of limestone, so strikingly seen in the case of the nepheline rocks of eastern Ontario, and in a large proportion of the occurrences of similar rocks in other parts of the world.

The only true granite met with in the district is a great intrusive mass which is crossed by the Thabeikkyin-Mogok road and which is exposed at intervals from about milepost 44 to milepost 30. It is a very even, fine-grained, typical gray granite, which at milepost 40.8 towers up above the road in beetling crags. Under the microscope it is seen to be composed of orthoclase with some biotite, and quite subordinate amounts of quartz and plagioclase with a few grains of rutile. Its contact with the sedimentary series, through which it cuts, is not seen on the road as low land conceals it on either side.

Just east of Sakangei, cutting this granite mass near its eastern margin, is an enormous pegmatite dyke which was opened up and worked extensively by the Burma Ruby Mines (Ltd.) some years ago. The dyke is at least 100 feet wide, although only one wall is

seen. this being the granite, here much decomposed. The dyke at the adjacent wall rock is very much kaolinized. The dyke consists of orthoclase almost entirely converted into kaolin with very large and fine crystals of quartz, many of which are as clear and transparent as glass. Individuals up to 6 inches in diameter were seen, but it is stated that even larger ones were found. Crystals of lepidolite measuring 6 inches or more across the cleavage faces, as well as muscovite and biotite and large, clear individuals of colorless topaz of perfect crystal form, were also found in the dyke. One of the latter had a diametral measurement of 3¼ inches. The dyke also contained small bunches of cassiterite here and there. The cassiterite, and the quartz crystals, sold to the Chinese traders for the manufacture of the various objects which the artists of that nation cut in quartz, were, it is understood, the chief products of economic value, and as these were not found in sufficient quantities to warrant the continuation of operations, work was abandoned and the openings are rapidly filling in under the action of the heavy tropical rains.

Leaving this granite intrusion and continuing on to the east, after an interval where the rocks are covered, the limestone series is again seen in frequent outcrops and the picturesque village of Kathe is reached, lying in a valley surrounded by high hills. Many of the lower hills are crowned by pagodas and the presence of many of the "twinlone" referred to below, which are seen in various parts of the plain, show that the underlying gem-bearing gravels have been tested at a great number of different places. It is at Kathe that the chief operations of the Burma Ruby Mines (Ltd.) are now being carried on. The road then rises and continuing on over the same limestone-gneiss series for a further distance of 9 miles descends into the Mogok Valley in which lies the little town of the same name. This is a most beautiful little valley, 10 miles long by 2 miles wide, and, like the Kathe Valley, is surrounded on all sides by hills, the highest reaching an elevation of 3,500 feet above the town, which has an elevation of 4,000 feet, clad with tropical vegetation, many picturesque pagodas being seen on prominent points and lending a distinctly Burmese appearance to the scene. A small stream winds through lower ground.

The beds of this series of limestones and gneisses, which are exposed almost continually along this section from Thabeikkyin to Mogok, strike north and south, although sometimes bearing a little to the east with a strike of as much as north 20° east. They dip uniformly to the east. The dip near the west end of the section is quite low, but 10 miles from the Irrawaddy the dip increases to 30°. About milepost 12 the strata are much contorted, but to the east of this, after a covered interval, the well-defined north and south strike is

again seen with an easterly dip of about 60°. This dip again decreases to about 30° at Kathe and Mogok but in the lit-pas-lit gneiss in the valley of the Yaynee River, just south of Mogok, rises to 70°. In the section as shown in Figure 2 the dip is represented as gradually increasing from Kathe to the Yaynee.

The strike of this limestone series on the road between Thabeikkyin and Mogok is not correctly shown by Barrington Brown,[4] but, as he states, before the construction of the road in question it was impossible to make accurate observations on the course of the limestone bands in this part of the area, owing to the very heavy fresh covering.

A microscopic study of the rock specimens from Mogok, brought to England by Barrington Brown, was made by the late Prof. J. W. Judd. In their joint paper the whole tenor of Professor Judd's description leads the reader to the conclusion that Judd believed that he had evidence from the microscopic studies of these rocks that the Archean limestones of Burma had originated from the alteration of certain pyroxene gneisses. Since the publication of this paper it has been repeatedly stated in print that this was the conclusion reached by Judd from his studies of the Mogok limestones.

When preparing the present article the writer, in looking over some old papers, found a letter written to him by Professor Judd under date of November 4, 1896, evidently in reply to a communication of his to Professor Judd, expressing surprise that he had reached such a conclusion. In this letter Professor Judd writes: "I must disabuse your mind of the idea that I want to put forward a theory to cover all the metamorphic limestones of Archean age. I do not think such a chemical theory as I have suggested at all likely to meet the case of the enormous mass of limestone regularly bedded over vast areas like those mentioned by Barrington Brown in Burma, or referred to by you in Canada. It is the special thin bands that contain rubies, spinels, and other marketable minerals that I am referring to." This letter is perhaps worthy of mention as no one would discover from a perusal of Professor Judd's paper that he intended by his theory to account merely for certain small streaks of limestone in the Mogok series and not for the whole succession of bedded limestones which are so strikingly displayed in this region.

That enormous developments of bedded limestones, such as those found in the great series under discussion, really represent highly altered and very ancient sediments is borne out in all respects by a study of their field relations, a conclusion which is also reached by LaTouche[5] in his study of the geology of the northern Shan States.

[4] Barrington Brown and Prof. John W. Judd: "The rubies of Burma and associated minerals." Phil. Trans., Royal Society, vol. 187, 1896.

[5] Records of the Geological Survey of India, Vol. XXXVI, pt. 3.

The little town of Mogok is situated on the valley floor, the population consisting of Burmese, Chinese, Shans, and some Indian Tamils. All look well and happy, requiring a very small income for their support and being apparently tolerably contented with what they have. Lines of sturdy, well-cared-for pack ponies with their quaintly clad drivers come over the hill trails from the Shan northern States and from China with loads of rice or other merchandise, and on market days the bazaars present a scene which, for color, movement, and picturesqueness of costume, can hardly be surpassed anywhere. These bazaars contain, even in this remote corner of the Far East, a large variety of western goods, as well as all manner of native products. The Burmese women, who carry on most of the retail trade of the country, usually wear skirts and jackets of very bright but well-matched colors, often of silk, with a large piece of some bright-colored fabric folded about the head, giving them a very graceful and picturesque appearance. Bath towels of western manufacture are now often used as a head covering in Burma or are worn thrown about the shoulders. Gems and native silverware are very generally offered for sale.

The rocks in the Mogok region are everywhere covered by a mantle of residual soil produced by the secular weathering. This seems to be heavier than in Ceylon. It is almost impossible to obtain specimens of the fresh rock except by blasting. Where good cuts have been made the rock is seen to have been bleached and kaolinized, while this kaolinized product is in its turn overlaid by a thick covering of red clay, which in some places approaches laterite in appearance, although it is less compact. This red clay, which also overlies the limestones, is remarkable for the manner in which it retains its form and even the tool marks upon it when cut into vertical walls or into steps running down steep declivities. Notwithstanding this fact, large quantities of the residual clay are washed down to the lower level by the heavy tropical rains, where it mingles with that formed by the weathering and solution of the rocks in the valleys, and in some places is subjected to further transportation by the action of streams running down the valleys, especially during the rains. Thus the residual soils pass into alluvial deposits.

There are three distinct ruby bearing areas in Upper Burma—those of Mandalay, Mytkynia, and the district about Mogok (including Kathe). The latter is by far the most important and constitutes the principal ruby producing tract in the world. Other areas will undoubtedly be discovered in the valleys of Upper Burma as time goes on; in fact, when the writer was going up the Irrawaddy, in the month of February, 1925, a party of gayly clad prospectors left the boat at Dundan, about 25 miles north of Thabeikkyin, a boom being

then in progress at a point 5 miles inland, where sapphires had been discovered in the low-lying paddy fields.

Practically no Europeans visited this district until the annexation of Upper Burma by the British in 1885. In 1889 the Secretary of State for India granted to Messrs. Streeter & Co., of Bond Street, a mining concession in the Mogok district, a seven-year lease being given, at a rent of 4 lakhs of rupees ($126,666) per annum, plus 16.66 per cent of the net profits. The Burma Ruby Mines (Ltd.) was thereupon formed to carry on mining. In 1896 the original lease was renewed for a period of 14 years, and in 1910 it assumed its present form, and runs till May 1, 1932, there being a fixed rental of 200,000 rupees per annum, plus 30 per cent of any excess of license income above 200,000 rupees per annum, the Government also claiming 30 per cent of the net profits. The Government gave the native miners every protection, in so much as they were not allowed to be in any way disturbed in their work or dispossessed except by purchase; otherwise, the company holds a monopoly of the right to mine or wash gems over the whole area designated as the Mogok Stone Tract.

The rubies, which form by far the most important of the gems yielded by this district, have their origin in the white crystalline limestones of the country rock, which have been described above. In the Mogok district (including Kathe) these limestones are intensely metamorphosed and are often very coarsely crystalline. It is stated that the more coarsely crystalline limestones are those which are richest in rubies. These gems are evidently developed in the limestones as one of the results of the intense metamorphism to which the district has been subjected. A. D. Morgan, the general manager of the Burma Ruby Mines (Ltd.), informed the writer that the sapphire, which while much less common than the ruby at Mogok, is nevertheless frequently found, occurs not in the limestone but in a rock, a specimen of which containing a large sapphire was submitted for examination, and which proved to be a granular white acid plagioclase intimately intergrown with orthoclase constituting a microperthite. The rubies and the other associated gems, however, do not occur in the limestones or their associated rocks in sufficient abundance to enable these to be worked for these minerals. Occasionally a native prospector will find a spot in the limestones where there is an unusual accumulation of rubies and will extract them, but this is rarely the case. The rubies and other gems are obtained in practically all cases from the residual or alluvial clays of the hill slopes or more usually of the valleys.

In the valley workings, as at Mogok and Kathe, there is a definite succession in these clays, the recognition of which is very important. In sinking a pit or shaft this first passes through reddish or yellowish clay which contains no gems; beneath this is found, resting on the

bedrock, a clay containing pebbles, and in this all the gems which the deposit contains are concentrated. This is known locally as "byon," and corresponds to the stoney clay which, in the gem region of Ceylon, occupies a similar position and is there known as "illam." When working such a deposit the overlying barren clays are first removed and the underlying byon is then carefully collected and taken directly to the mill.

Upon the removal of this byon, the surface of the underlying limestone is seen to present a curious appearance. It is a surface of solution and an immense number of "hoodoos"—10, 20, or 50 feet high and of sharp jagged outline—rise from the general surface, if indeed there can be said to be one, while deep, irregular crevices run down into the limestone, often to great depths. When the residual clay has been entirely removed from the valley floor, as is the case in the exhausted workings in the valley running through the town of Mogok, it is almost impossible to cross the valley except on specially constructed roads or paths owing to the extreme irregularity of the limestone surface, the spectacle presented when looking across the valley being weird in the extreme. The byon lying in the pockets and depressions in the very irregular limestone floor and filling up the crevices penetrating it, is often very rich in gems and, although contrary to law, the natives frequently, when unobserved, busy themselves in digging out the byon from such holes and corners and washing it for the gems that it may yield.

The native methods of mining are three in number, namely, by loodwins, hmyaudwins, and twinlone.

The loodwins are workings by which the byon in caves and fissures in the limestone is extracted and then washed.

The hmyaudwins are cuttings driven into the rain-wash on the hill slopes, the extracted byon being washed by sluicing, water being brought from some adjacent stream.

Twinlone—in this, which is the commonest method, pits are sunk into the alluvium of the valleys from 2 to 9 feet square, and by means of these the gem-bearing gravel is raised to the surface, often from a considerable depth. After a few feet have been excavated, strong posts, 12 feet in length, are driven in vertically around the sides of the pit and short timbers are fitted between adjacent posts, and a lagging of twigs and dry grass is provided to support the walls. As the sinking progresses, new posts are sunk. The excavated earth and any water which accumulates is raised to the surface by a bucket—or an old oil can—attached to one end of a bamboo balance pole swinging on a high bamboo frame as shown in Plate 1. As already mentioned, this device is also in use in Ceylon. A great number of these pits, each with its bamboo frame and swinging pole, are seen distributed far and wide over the plain of Kathe, showing the extended prospect-

ing operations which have been carried out in this area, which is at present the largest producer in the Mogok concession.

The Burma Ruby Mines (Ltd.), however, desiring to work these deposits on a large scale, adopted western methods of excavating and transporting the materials to be handled, and built mills provided with modern concentrating machinery for the purpose of separating the gems.

The workings at the town of Mogok, as they appeared some years ago when mining here was at its maximum development, are shown in Plate 7, which is taken from a photograph reproduced in Escard's "Les Pierres Precieuses" (Paris, 1914). This stretch of alluvium has now been worked out. The company is now working at Enjouk, on the margin of the Mogok Valley, as well as on a small scale at Bigom, Nanyasen, and other points, but its chief operations are now centered at Kathe, 8 miles to the west of Mogok. Unfortunately the rubies here are very often coarse and rough and not of the best color.

At Kathe the geological conditions are the same as those at Enjouk and as in the old exhausted workings at the town of Mogok. The country rock is white crystalline limestone, often holding numerous flakes of graphite, phlogopite, and other minerals, with many interstratified bands of harder silicate rocks, chiefly plagioclase-scapolite gneiss resembling the limestones in color and a few other allied gneisses. One darker band was found to be composed essentially of a plagioclase and a brown hornblende, with a little pyroxene, biotite, scapolite, and iron ore as accessory constituents. Nothing that could be recognized as an igneous intrusion was seen in the workings.

These rocks under conditions of secular decay and solution present the remarkably irregular "hoodooed" surface already described, covered with a mantle of residual clay. This, with the underlying limestone series, is seen in Plate 5, which is one of the working faces at Kathe. The byon lies directly on the irregular limestone surface and is overlain by the barren clays.

The byon is brought to the mill in trucks, hauled from the working face by an endless wire cable, and thrown first on a grate of spaced iron bars, which separates the large pieces of rock. The material which falls between them goes to two successive sets of revolving trommels into which water is fed. The coarser material from these goes directly to a table and is hand sorted by one of the company's officers. Here, when the writer was visiting the mill, a ruby rather over 1 inch in diameter was found.

The finer material from the last set of trommels goes into diamond washing pans, the gravel which is retained by these representing 1 per cent of the original byon fed to the mill. This is then carried to a series of jigs which reject three-quarters and keep one-quarter of the product received from the diamond washing pans. This

quarter of 1 per cent of the original material is then placed on sorting tables having a surface consisting of an iron plate and is sorted over by one of the company's officers (a European). He takes out any large gems which may be present. The gravel then passes on to a series of tables around each of which a number of men (natives) are seated, about six to a table, who re-sort it very carefully, removing every stone which has any value. Each man wears on his head a large box with a front of iron gauze which prevents him from secreting any stones in his mouth or from swallowing them. A foreman (native), who is supposed to be strictly honest, watches the operations at each table. These men are very expert at stealing stones and are carefully searched before they leave the building at the close of the day. The exhausted tailings are then taken from the mill and sold to a Burmese woman, who buys the whole output and who then divides it up into a series of little conical heaps and sells them at a rupee a piece to other women, who go over the pile grain by grain and collect from it every minute ruby which it may contain and sell these to be used in making watch bearings and for other purposes to which they may be of use. A group of women sorting over these little piles is seen in Plate 6. The gems which are obtained in the mill are sent to the headquarters of the company in the town of Mogok and are subjected to a final sorting and classification into the various grades which are then marketed. For this purpose small quantities at a time are taken by certain expert gem sorters, whose honesty is undoubted, and placed on shallow highly polished brass plates about a foot and a half in diameter and sorted over in the bright sunlight. These sorters are seen at work on the veranda of the company's office at Mogok, in Plate 6. The man at the margin of the photograph on the right is cutting a ruby on a wheel turned by a second man.

In addition to rubies, other gems are found in the byon, although less abundantly. On looking over the concentration product as it comes to the office from the mill there can be distinguished: 1. Rubies of various intensities of color. 2. Sapphires, blue, yellow, or white, showing similar variations in color. 3. Spinels usually pink in color, the intensity of the color differing in different individuals. These often show the characteristic octahedral form. These spinels are, next to the ruby, the most common gem in this district. 4. Common opaque corundum. 5. Tourmalines. 6. Zircons. 7. Quartz. 8. Other minerals, such as beryl, scapolite, apatite, and fibrolite (very rare).

While Mogok has produced the finest rubies which have ever been found, the value of the output seems small when compared with outputs of districts where metallic ores are mined. From 1899 to 1905 the mines yielded annually gems to the value of about $450,000. In

later times the yield has fallen off and is naturally subject to fluctuation from year to year according to the value of the stones recovered. This is indicated by the following figures, which show the value of the rubies produced in Burma in some recent years:

1913	$228,304
1914	198,603
1915	165,000
1917	212,210
1919	425,800
1921	224,414
1922	224,409

The great increase in the value of the output for 1919 was due in part to the finding in that year of an exceptionally valuable ruby, which was sold for three lakhs of rupees ($100,000).

In addition to these gems, most of the jade, which is cut and polished in China, comes from northern Burma, and not very far from the jade mines are deposits of beautiful amber. As this country is opened up in future years other valuable deposits will probably also be found.

A number of minerals of exceptional interest were obtained by the author in Burma, more especially from the district of the ruby mines about Mogok. Among these brief reference may be made to the following, a full description of which will be found elsewhere.[6]

Chrysoberyl.—This species has not hitherto been described from Burma, but was found near Mogok in the very unusual form of simple crystals, transparent and of a sea-green color, as well as in trillings of a pale yellow color. These show a number of forms which have never been observed in this species from other localities.

Sillimanite.—This species occurs, although rarely, as rolled pebbles accompanying the ruby in alluvial deposits. One specimen showed a cleavage apparently parallel to a macro-dome, which renders it possible to measure the relative length of the vertical axis, which has been unknown in the case of this species hitherto. These measurements show that there is a close correspondence between the axial relations of sillimanite and those of the related minerals, andalusite and cyanite.

Nepheline.—This species, hitherto unknown from Burma, was found in a coarsely crystalline urtite associated with the crystalline limestones near Sinkwa.

Sodalite.—This mineral, having a deep lilac color, was found associated with nepheline at a second locality, namely, the Tajonngnadine mine at Mogok.

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[6] Frank D. Adams and R. P. D. Graham, "On some minerals from the ruby mining district of Mogok, Upper Burma." Trans. Royal Society of Canada, Vol. XX, sec. 4, 1926.

Fosterite.—Occurs as an abundant accessory mineral in certain of the crystalline limestones at Mogok. It has not been formerly reported from Burma.

In the great pegmatite dyke at Sakangei, lepidolite in very large crystals, as well as muscovite, topaz, cassiterite, and very large crystals of quartz were seen. The topaz occurs in clear, transparent, nearly colorless crystals several inches in length. A large crystal examined is unique in that it is terminated at one end by the basal plane above and at the other end by pyramidal forms.

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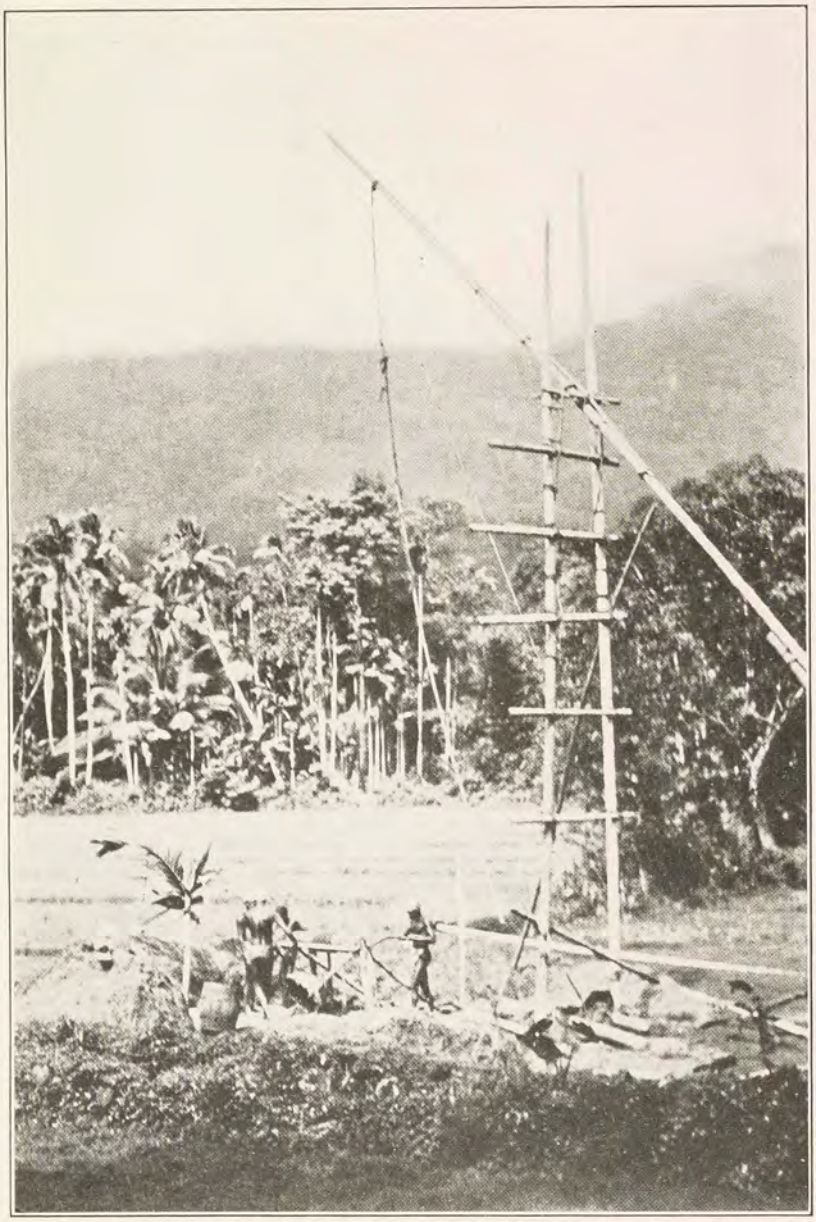
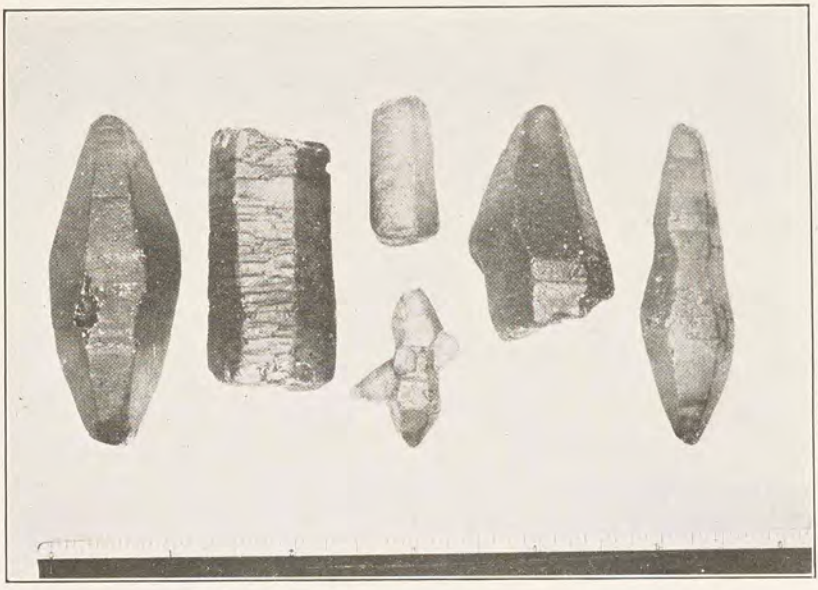
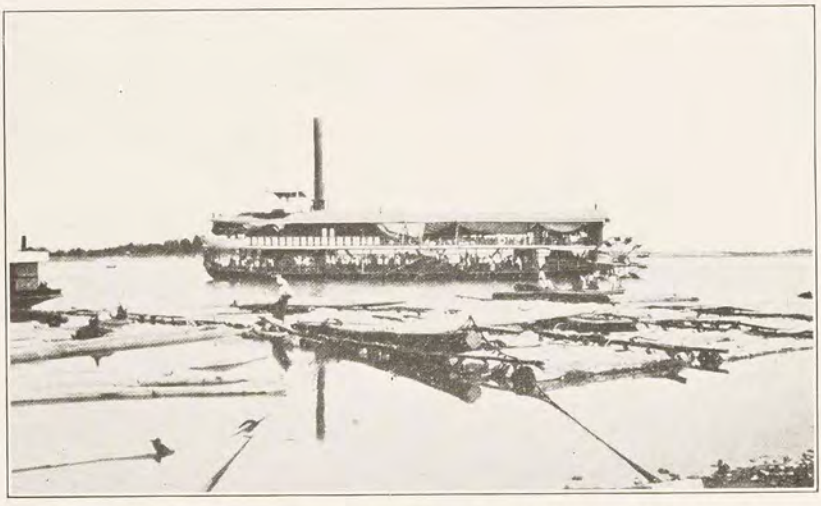


SINGHALESE SINKING A SHAFT FOR GEMS, PALMADULLA, CEYLON



1. YELLOW SAPPHIRES FROM WORKINGS AT PALMADULLA, CEYLON

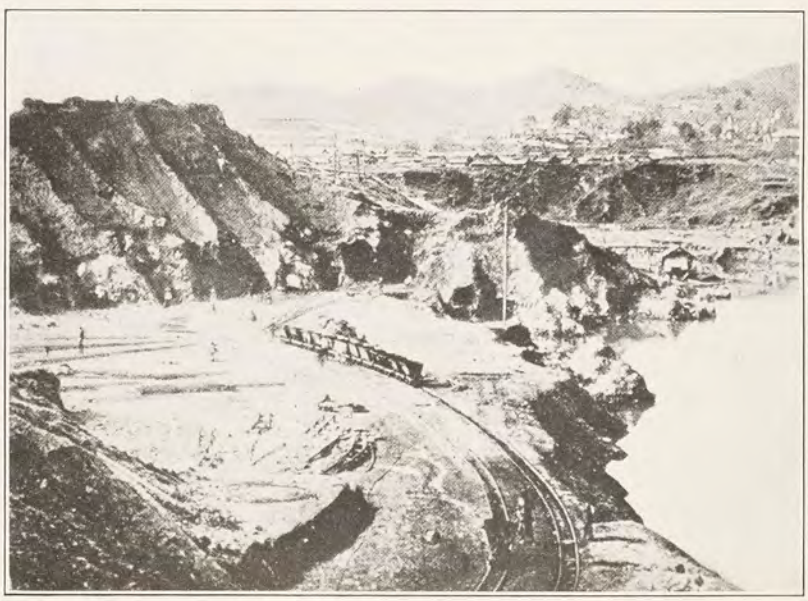


2. STEAMBOAT ON THE IRRAWADY RIVER. RAFT OF TEAK LOGS IN FOREGROUND

1. GROUP OF NATIVES ON THE BANK OF THE IRRAWADY RIVER AWAITING THE ARRIVAL OF THE STEAMBOAT

2. RAFT OF TEAK LOGS ON THE IRRAWADY RIVER

1. ROAD BETWEEN THABEIKKYIN AND MOGOK RUNNING THROUGH BURMESE FOREST RESERVE



2. RUBY MINES AT MOGOK IN PERIOD OF MAXIMUM DEVELOPMENT

WORKING FACE IN THE RUBY MINES AT KATHE, BURMA

1. WOMEN SORTING TAILINGS FROM THE MILL AT KATHE FOR MINUTE RUBIES

2. SORTING AND CUTTING GEMS AT THE OFFICE OF THE BURMA RUBY MINES (LTD.), MOGOK

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