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OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXVII, PART 2.

NOETLING: THE OCCURRENCE OF PETROLEUM IN BURMA, AND ITS TECHNICAL EXPLOITATION.

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOLUME XXVII, PART 2.

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YENANGYAUNG OIL-FIELD, TWINGON AREA, LOOKING NORTH.

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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PART I.—HISTORICAL AND GEOLOGICAL.

CHAPTER I.—HISTORICAL SUMMARY UP TO 1886.

A.—Legendary Times.

If we are to believe the native tradition, the origin of the Yenangyaung oil-fields dates back to those far remote times when wonders happened in which our sceptical age refuses to believe. The following is a legend about the origin of the Yenangyoung oil-fields told me by the Bemè Ywaôk :—

"When King Alaungsitha was 10 years old, he contemplated a visit to Mount Meru, the centre of the Universe, and ordered the building of a magnificent raft, which took five years to be finished. In due course the king started on his journey. On arriving near a hill called Minlin (Minlindaung is about a mile south of the Bemè oil-fields) the ship was halted and seven of the Queens asked to be permitted to amuse themselves on the shore. Permission was granted on condition that they should not be away for a long time. When they got ashore, they found a quantity of fragrant liquid oozing out from the rock, with which they besmeared themselves, and the enjoyment they indulged in was of such an engrossing nature that they became oblivious of the injunction not to tarry. For this disobedience the Queens were punished with death. Before they died, they implored that the liquid which was the indirect cause of their death might be made to change its nature. The fragrant liquid was consequently turned into earth-oil."

Through the kindness of Mr. Gibson, Extra Assistant Commissioner, I received a somewhat different account of the legend. The account gives the abridged contents of a favourite "poway"[1] frequently played at Yenangyoung. It runs as follows:—

"During the reign of Poph Saw Rahan, the eleventh king of Pagan, in the year 2 B. E. (A. D. 640), the Myothuggi[2] of Kyaukka Myo[3] and his relatives dug a large tank about two miles east of their town for the benefit of the inhabitants. This tank was called Myitta-kan, *i.e.*, "constructed to gain merit." Before its completion an earthquake occurred, and on the ground cracking about the tank it filled with highly perfumed waters (Yenanthasi), which attracted thousands of pilgrims and proved a source of great benefit to the Myothuggi and his family. It was subsequently prophesied by a Rahan (=Pôngyi),[4] named Pônnawadda Mabi, that at the command of a king the perfumed waters of Yenanthasi would loose their sweet scent and change into an oily liquid emitting a noxious odour, and henceforward be known by the name of Yenan; but these effects, far from causing any distress to the descendants of the Myothuggi, who would be 24 in number, would on the contrary benefit them greatly, as the Yenan would be of great demand for preserving of "pezois" (=palm leaf with sacred writings) and for illuminating pagodas and temples.

Years passed, and the time for the fulfilment of the prophecy was at hand. The King Alaungsitha Mingyi of Pagan having heard that Kyaukka Myo was a famous town and contained many wonders, made up his mind to pay the place a visit. Accordingly he left Pagan on the 4th day of the waxing moon of the month of Pyatho 460, Burmese Era (=January 1099 A.D.), with the following retinue:—

28 ladies under charge of a eunuch designated Kye Pônna,
100 bos (=officers and wise men), 80,000 troops, rank and file,
12 towing boats and rafts,

[1] Poway, is the national Burmese drama.
[2] Headman.
[3] Rockcave town, now Yenangyoung.
[4] Burmese priest or monk.

and on the 7th day of the same month landed at Kyaukka Myo. On arrival he lost no time in fulfilling his desire of visiting the wonders of the place. On the 8th, on returning from one of these excursions in the evening, he discovered that seven of the ladies, named the Myozas[1] of Nyoungôk, Nyoungywè, Salè, Talin, Kyabin, Popa and Nyoungyan, and the eunuch Kye Pônna of his establishment were missing. He was much enraged, and immediately went in search of them. He reached a hill called Thuwanagiri, and there tarried for the night, being entertained by a Zawgyi (=magician) who resided there: hence this hill is called Minlindoung to this day. The next morning, the 9th, he discovered the truants in high glee on the banks of the lake of scented waters, and, enraged at the sight, he killed them. They immediately turned into Nats.[2] When his passion had cooled down and he had meditated on the crime he had committed, he blamed the Yenanthasi as being the cause of it. So, calling to his aid the miraculous powers which he possessed, he changed the perfume of the waters into its present malodorous state. From that day to the present it is known as "Yenan" =stinking water. On the 10th the king attempted to leave Kyaukka Myo, but none of its rafts would move; and on consulting his wise men was told that the natseins desired to be provided for and would not allow him to proceed till he had made provision for them. A meeting with the natseins was arranged, and an amicable settlement was come to, by which the king agreed that the proceeds of the sale of the Yenan were to be devoted to the eight natseins. The king also commanded that the Yenan producing soil be only within a certain area, which was to be held by the Yogas (*viz.*, the descendents of the digger of the tank), and that the limits of such lands be laid down by drawing a straight line from a place

[1] This might be translated "duchesses"; literally it means "eater of the town," because a Myotza derived his income from the revenue of the town that gave him his title.

[2] A kind of greenfaced demon; all who die of unnatural causes are very liable to turn into a nat.

called Thelagaza or Kyouksin (= Rock elephant) to Thawanagiri (= Minlindoung), then from the centre of this line to mark off two points, one on the west at the same distance as from this centre to Minlindoung, and that the boundary be from Kyouksin to a point east, thence to Minlindoung, thence to a point west, and thence to Kyouksin. After these commands the king was able to leave for Pagan, reaching it on the 14th of that month."

I may be permitted to dwell a little on this remarkable legend, because it contains a very curious fact, of which an explanation is highly difficult.

At first the legend seems to prove the great age of the Yenangyoung oil-field. We may conclude that in remote times the Yenangyoung oil-field was systematically exploited and the oil used for all sorts of purposes.

A remarkable fact furthermore is the allusion to the 24 descendents of the man who first dug the tank, that they were to be the sole owners of the Yenan. In a later chapter it will be seen that 24 families claim the hereditary right of exploiting the oil. Of course this may be a subsequent addition to the original legend, recently inserted at the instigation of a crafty Twinzayo in order to give an ancient legendary background to their claims.

The most remarkable part of the legend is the delimitation of the area by the king. The magnetic bearing of the long axis of this tract agrees with the strike of the strata: in fact it coincides with the axis of the anticline. The recent borings have proved the limited extension of the Yenangyoung oil-field which falls rather short of the boundaries laid down by King Alaungsitha.

B.—Historical Times.

I think there is hardly a volume of travels in Burma in which the Yenangyoung oil-field is not mentioned. The reason of this is quite plain. Yenangyoung being on the banks of the Irawadi, the highway of Burma, every traveller who visited Upper Burma was bound to pass the famous place. It would be quite useless to quote all the books in which the Yenangyoung oil-field has been mentioned: it is sufficient to refer to the most important works only.

1755. Captain George Baker.

The earliest account of the Yenangyoung oil-fields which I have been able to trace will be found in Captain George Baker's Journal of an Embassy to the King of Burma in 1755;[1] he says: "*Raynan-Gome* I take to lye 25′ South of *Sallee-mue* (= Salè Myo)......At this Place there are about 200 Families, who are chiefly employed in getting *Earth-Oil* out of Pitts, some five Miles in the Country."

1782. W. Hunter.

In 1782 W. Hunter, A. M. Surgeon, in the employ of the Honourable East India Company, who visited Burma, wrote as follows: "There is found here, swimming on the surface of the water in certain wells, a kind of petroleum or naphta which is used like oil for burning and also for making unctuous compositions for painting the sides of the vessels."

1795. M. Symes.[2]

The most reliable of the early accounts on the Burmese oil-fields will be found in Symes' Embassy to Ava, of which I give here an extract, omitting the less important parts:—

"The hills, or rather hillocks, were covered with gravel, and yielded no other vegetation than a few stunted bushes. The wheels (of the bullock carts) had worn ruts deep into the rock, which seem to be rather a mass of concreted gravel, than hard stone, and many pieces of petrified wood lay strewed about. It is remarkable, that wherever these petrifications were found, the soil was unproductive, and the ground destitute of verdure. The evening being far advanced, we met but few carts; those we did observe were drawn each by a pair of oxen, and of a length disproportionate to the breadth to allow space for the earthen pots that contained the oil. It was a matter of surprise to us, how they could convey such brittle ware, with any degree of safety, over so rugged a road: each pot was packed in a separate basket, and laid on straw, notwithstanding which precaution, the ground all the way was strewn with the fragments of the vessels, and wet with oil; for no

[1] Oriental Repertory, published at the charge of the East India Company, by Dalrymple, London, 1791, page 172.

[2] Michael Symes. An account of an Embassy to the kingdom of Ava, sent by the Governor-General of India in the year 1795. London, 1800, volume III, pages 232 to 238.

care can prevent the fracture of some in every journey. As we approached the pits, which were more distant than we had imagined, the country became less uneven, and the soil produced herbage; it was nearly dark when we reached them, and the labourers had retired from work. There seemed to be a great many pits within a small compass : walking to the nearest, we found the aperture about 4 feet square, and the sides, as far as we could see down, were lined with timber; the oil is drawn up in an iron pot, fastened to a rope passed over a wooden cylinder which revolves on an axis supported by two upright posts. When the pot is filled, two men take the rope by the end, and run down a declivity, which is cut in the ground, to a distance equivalent to the depth of the well; thus when they reach the end of their track, the pot is raised to its proper elevation, the contents, water and oil together, are then discharged into a cistern, and the water is afterwards drawn off through a hole at the bottom. Our guide, an active intelligent fellow, went to a neighbouring house and procured a well rope, by means of which we were enabled to measure the depth, and ascertained it to be thirty-seven fathoms, but of the quantity of oil at the bottom we could not judge : the owner of the rope who followed our guide affirmed, that when a pit yielded as much as came up to the waist of a man, it was deemed tolerably productive; if it reached to his neck, it was abundant; but that which rose no higher than the knee, was accounted indifferent. When a well is exhausted, they restore the spring by cutting deeper into the rock, which is extremely hard in those places where the oil is produced. Government farm out the ground that supplies this useful commodity; and it is again let to adventurers who dig wells at their own hazard, by which they sometimes gain, and often lose, as the labour and expense of digging are considerable. The oil is sold on the spot for a mere trifle; I think two or three hundred pots for a tackal or half-a-crown. The principal charge is incurred by transportation and purchase of vessels."

In the 3rd part of the Manual of Geology of India, 1st edition, page 151, it is stated that Symes gives the number of wells as 500 and the annual yield as something like 56,000,000 viss (90,900 tons). I do not know where the author of the Manual obtained this statement from, as I cannot find any reference to it in my copy of Symes' Embassy to Ava.

Symes' description of the features of the country in all its briefness affords such a true picture of the dry, barren land around Yenangyoung that one might suppose the author had visited Yenangyoung in our times—not a hundred years ago. There are still the same dusty roads worn by deep wheel tracks, strewn with pieces of broken earthen pots and saturated with spilt oil, and there are still the same creaking, shrieking carts coming from the oil-fields while

I write these lines, as they did a hundred years ago. But the most striking feature in Symes' account is the description of the wells, the method of extracting the oil, and the way of carting it down to the shore. In all this there has not been the slightest change, everything is exactly as it was a hundred years ago, only that now-a-days clay pots are used for hauling up the oil; in fact, I rather believe that this was also the case during Symes' visit, and that the "iron" pot which he noticed was an exception.

The whole description of the oil-fields is, however, not so exhaustive as it might be, and, if seen in the light of a report written only two years later, some of Symes' statements have to be accepted with the greatest care. In the first place it cannot be made out which of the two tracts—Bemè or Twingon—was visited by Symes. As Captain Cox particularly mentions two distinct oil-fields, I cannot imagine that within such a short time as two years a second oil-field with quite a number of wells could have sprung up. I believe, however, that Symes visited Bemè, as all his successors did.

The next statement refers to the proprietary rights in the land. Symes' statements are too vague, and are contradicted altogether by the report of Captain Cox, whose statements have been independently confirmed by the descriptions of subsequent visitors. It is hardly possible that such wide reaching changes in the proprietary rights of the oil bearing land could have happened within two years, and we shall presently see that Captain Cox's statements deserve much more credit, even had they not been confirmed subsequently.

As regards the number of wells, Symes is certainly wrong. There cannot possibly have been 500 wells in existence, as the survey of 1890-91 has proved that there were then 602 wells all told, of which at least 76 have been constructed during the three preceding years, 120 more wells are certainly not older than 35 years. This reduces their number to 304, if we assume that no new wells have been dug between 1797 and 1855. As this is, however, not very probable, we are obliged to assume that at the time when Cox visited the oil-fields the number of wells was even smaller than 300. I shall return to this subject in a following chapter. The statement about the production must necessarily be equally exaggerated, even if we suppose that the average yield per well was higher in those days than it is now.

The next report about the Yenangyoung oil-field was written only two years later by Captain Cox, who visited the oil-fields in 1797. The account of his visit was published in the Asiatic Researches (Volume VI, pages 127 to 136, 1799), and as it is highly interesting in many ways, I give it here *verbatim*:—

"*An* ACCOUNT *of the* PETROLEUM WELLS *in the* BURMESE *Dominions, extracted from the Journal of a voyage from* RANGHONG *up the River* ERAI WUDDEY *to* AMARAPOORAH, *the present Capital of the* BURMHA *Empire by Captain* HIRAM COX, *Resident at* RANGHONG.

"*Saturday, 7th January 1797.*

"Wind easterly, sharp and cold, thick fog on the river until after sunrise, when it evaporated as usual, but soon after collected again, and continued so dense till 8-30 A.M. that we could barely see the length of the boat.

"Thermometer at sun rise 52°, at noon 74°, in the evening 69°. General course of the river north 20° west, main breadth from 1 to 1½ miles; current about 2½ miles per hour.

"East bank, high rugged barren downs, with precipitous cliffs towards the river, of free stone intermixed with strata of quartz, martial ore, and red ochre; beech moderately shelving covered with fragments of quartz, silex, petrifactions and red ochre, with rocky points projecting from it into the river.

"Western bank, a range of low sandy islands, covered with a luxuriant growth of reeds. These at present narrow the stream to three quarters and in some places to half a mile, but are overflowed in the rains; the main bank rather low and sandy, subject to be overflowed, its whole breadth about 3 miles to the foot of a range of low woody hills, which in point of vegetation form an agreeable contrast to the eastern shore. These hills are bounded to the westward at the distance of about 20 miles from the river by an extensive range of high mountains, cloathed with wood to their summits.

"At half past ten A.M. came to the lower town of *Rainanghong*, a temple in it of the antique *Hindoo* style of building. At noon came to the centre town of Rainanghong (literally the town through which flows a river of earth oil), situated on the east bank of the river in latitude 20° 26′ north and longitude 94° 45′ 54″ east of *Greenwich*, halted to examine the wells of *Petroleum*.

"The town has but a mean appearence, and several of its temples, of which there are great numbers, falling to ruins: the inhabitants however are well dressed, many of them with gold spiral ear ornaments, and are undoubtedly rich from the great profit they derive from their oil wells, as will be seen below.

"At two P.M. I set off from my boat, accompanied by the *mewthaghee* or zemindar of the district and several of the merchant proprietors, to view the wells. Our road led to E.N.E. through dry beds of loose sand in the water-courses, and over rugged arid downs and hillocks of the same soil as described above, the growth on them consisting of scattered plants of *Euphorbium*, the *Cassia* tree which yields the *Terra Japonica*, commonly called *cutch* or *cuth*, and used throughout *India* as a component part of a *beera* of paun, also a very durable timber for lining the oil wells, and, lastly, the hardy *bair* or wild plumb common in Hindustan.

"The sky was cloudless, so that the sun shone on us with undiminished force, and being also unwell, I walked slowly, and as we were an hour walking to the wells, I therefore conclude they are about three miles distant from the river; those we saw are scattered irregularly about the downs, at no great distance from each other, some perhaps not more than 30 or 40 yards. At this particular place we were informed there are 180 wells, four or five miles to the N.E. 340 more.

"In making a well the hill is cut down so as to form a square table of fourteen or twenty feet for the crown of the well, and from this table a road is formed, by scraping away an inclined plain for the drawers to descend in raising the excavated earth from the well, and subsequently the oil. The shaft is sunk in a square form, and lined, as the miner proceeds, with squares of *Cassia* wood staves. These staves are about six feet long, six inches broad, and two thick; are rudely jointed and pinned at right angles to each other, forming a square frame about four and a half feet in clear for the uppermost ones, but more contracted below. When the miner has pierced six or more feet of the shaft, a series of these square frames are piled on each other, and regularly added to at top, the whole gradually sinking, as he deepens the shaft, and securing him against the falling in of the sides.

"The soil or strata to be pierced is nearly such as I have described the cliffs to be on the margin of the river, that is, first, a light sandy loam intermixed with fragments of quartz, silex, etc.; second, a friable sand stone, easily wrought, with thin horizontal strata of concrete or martial ore, talc, and indurated argill (the latter has this singularity, it is denticulated, its lamina being perpendicular to the horizontal lamina of the argill on which it is seated) at from ten to fifteen feet from the surface, and from each other, as there are several of these veins in the great body of free stone. Thirdly, at seventy cubits, more or less, from the surface, and immediately below the free stone, a pale blue argillaceous earth (shistous) impregnated with the petroleum and smelling strongly of it. This they say is very difficult to work, and grows harder as they get deeper, ending in schist and slate, such as found covering veins of coal in *Europe*, etc. Below this schist at the depth of about 130 cubits is coal. I procured some, intermixed with sulphur and pyrites which had been taken from a well deepened a few days before my arrival, but deemed amongst them a rarity, the oil in general flowing at a smaller depth. They were piercing a new well when I was there, had got to the depth of eighty cubits, and expected oil at ten or twenty cubits more.

"The machinery used in drawing up the rubbish, and afterwards the oil from the well, is an axle crossing the center of the well, resting on two rude-forked stanchions, with a revolving barrel on its center, like the nave of a wheel, in which is a score for receiving the draw rope, the bucket is of wicker work, covered with dammer, and the labour of the drawers, in general three men, is facilitated by the descent of the inclined plain, as water is drawn from deep wells in the interior of *Hindostan*.

" To receive the oil, one man is stationed at the brink of the well, who empties the bucket into a channel made on the surface of the earth leading to a sunk jar, from whence it is ladled into smaller ones, and immediately carried down to the river, either by coolies or on hackeries.

" When a well grows dry, they deepen it. They say none are abandoned for barrenness. Even the death of a miner, from mephitic air, does not deter others from persisting in deepening them when dry. Two days before my arrival a man was suffocated in one of the wells, yet they afterwards renewed their attempts without further accident. I recommended their trying the air with a candle, etc., but seemingly with little effect.

" The oil is drawn pure from the wells, in the liquid state as used, without variation, but in the cold season it congeals in the open air, and always loses something of its fluidity; the temperature of the wells preserving it in a liquid state fit to be drawn. A man who was lowered into a well of 110 cubits, in my presence, and immediately drawn up perspired copiously at every pore; unfortunately I had no other means of trying the temperature. The oil is of a dingy green and odorous; it is used for lamps and boiled with a little dammer (a resin of the country) for painting the timbers of houses, and the bottoms of boats, etc., which it preserves from decay and vermin; its medicinal properties known to the natives is as a lotion in cutaneous eruptions, and as an embrocation in bruises and rheumatic affections.

" The miners positively assured me no water ever percolates through the earth into the wells, as has been supposed, the rains in this part of the country are seldom heavy, and during the season a roof of thatch is thrown over the wells; the water that falls soon runs off to the river, and what penetrates into the earth is effectually prevented from descending to any great depth by the increasing hardness of the oleagenous argill and shist; this will readily be admitted, when it is known that the coal mines at *Whitby* are worked below the harbour, and the roof of the galleries not more than fifty feet from the bed of the sea, the deficiency of rain in this tract may be owing to the high range of mountains to the westward, which range parallel to the river and arrest the clouds in their passage, as is the case on the eastern side of the peninsula of *India*.

" Solicitous to obtain accurate information on a subject so interesting as this natural source of wealth, I had all the principal proprietors assembled on board my boat, and collected from them the following particulars, the foregoing I learned at the wells from the miners and others.

" I endeavoured to guard against exaggeration, as well as to obviate the caution and reserve which mercantile men in all countries think it necessary to observe, when minutely questioned on subjects affecting their interests, and I have to hope my information is not very distant from the truth.

"The property of these wells is in the owners of the soil, natives of the country, and descends to the heirs generally as a kind of entailed hereditament, with which it is said Government never interferes, and which no distress will induce them to alienate. One family perhaps will possess four or five wells, I heard of none who had more, the generality have less, they are sunk by, and wrought for, the proprietors; the cost of sinking a new well is 2000 tecals flowered silver of the country, or 2500 sicca rupees; and the annual average net profit 1000 tecals, or 1250 sicca rupees.

"The contract price with the miner for sinking a well is as follows: for the first forty cubits they have forty tecals, for the next forty cubits three hundred tecals, and beyond these eighty cubits to the oil they have from thirty to fifty tecals per cubit, according to the depth (the *Burmha* cubit is nineteen inches *English*); taking the mean rate or forty tecals per cubit and one hundred cubits as the general depth at which they come to oil, the remaining twenty cubits will cost 800 tecals, or the whole of the miner's wages for sinking the shaft 1140 tecals; a well of 100 cubits will require 950 cassia staves, which at 5 tecals per hundred will cost 47½ tecals. Portage and workmanship, in fitting them, may amount to 100 tecals more; the levelling the hill for the crown of the well, and making the draw road, etc., according to the common rate of labour in the country, will cost about 200 tecals, ropes, etc., and provisions for the workmen which are supplied by the proprietor when making a new well; expenses of propitiatory sacrifices, and perhaps a signiorage fine to government for permission to sink a new well consume the remaining 512½ tecals. In deepening an old well they make the best bargain in their power with the miners, who rate their demand per cubit according to its depth, and danger from the heats or mephitic air.

"The amount, produce, and wages of the labourers who draw the oil, as stated to me, I suspect was exaggerated or erroneous from misinterpretation on both sides.

"The average produce of each well per diem, they said, was 500 viss or 1825 lbs. avoirdupois, and that the labourers earned upwards of eight tecals each per month, but I apprehend this was not meant as the average produce or wages per every day or month throughout the year, as must appear from further examination on the subject, where facts are dubious we must endeavour to obtain truth from internal evidence. Each well is worked by four men, and their wages is regulated by the average produce of six days' labour, of which they have one sixth, or its value at the rate of one and a quarter tecals per hundred viss, the price of the oils at the wells; the proprietor has an option of paying their sixth in oil, but I understand he pays the value in money, and if so, I think it is as fair a mode of regulating the wages of labour as anywhere practised, for in proportion, as the labourer works he benefits, and gains only as he benefits his employer. He can only do injury by over-working himself, which is not likely to happen to an *Indian;* no provisions are allowed to the oil drawers, but the proprietor supplies the ropes, etc. and lastly the king's duty is a tenth of the produce.

"Now, supposing a well to yield 500 viss per diem throughout the year, deducting one sixth for the labourers and onetenth for the king, there will remain for the proprietor, rejecting fractions, 136,876 viss, which at $1\frac{1}{4}$ tecals, the value at the wells, is equal to 1710 tecals per annum. From this sum there is to be deducted only a trifle for draw ropes, etc., for I could not learn that there was any further duties or expense to be charged on the produce, but the merchants say they gain only a neat 1000 tecals per annum for each well, and as we advance we shall have reason to think they have given the maximum rather than the minimum of their profits, hence, therefore, we may infer that the gross amount produce per annum is not 182,500 viss.

"Further the four labourers' shares of onesixth deducting the king's tythe, will be 2250 viss per month of thirty days or in money at the above price twenty-eight tecals fifty avas, or seven tecals twelve avas each per man per month, but the wages of a common labourer in this part of the country, as the same persons informed me, is only five tecals per month when hired from day to day; they also admitted that the labour of the oil drawers was not harder than that of common labourers, and the employment was in no way obnoxious to health. To me the smell of the oil was fragrant and grateful, and on being more indirectly questioned (for on this part of the subject perhaps owing to the minuteness of my enquiries I observed most reserve) they allowed that their gain was not much greater than the common labourers of the country, nor is it reasonable to expect it should, for, as there is no mystery in drawing of oil, no particular hardships endured, or risk of health, no compulsion or prevention pretended, and, as it is the interest of the proprietors to get their work done at the cheapest rate, of course the numbers that would flock to so regular and profitable an employment would soon lower the rate of hire nearly at least to the common wages of the country; besides I observed no appearance of affluence amongst the labourers, they were meanly lodged and clad, and fed coarsely, not on rice, which in the upper provinces is an article of luxury, but on dry grains and indigenous roots of the nature of *Cassada*, collected in the wastes by their women and children; further it is not reasonable to suppose that these labourers worked constantly, nature always requires a respite, and will be obeyed, however much the desire of gain may stimulate, and this cause must more particularly operate in warm climates to produce what we often improperly call indolence. Even the rigd Cato emphatically says, that the man who has not time to be idle is a slave. A due consideration of this physical and moral necessity ought perhaps to vindicate religious legislators from the reproaches too liberally bestowed on them for sanctioning relaxation; be that as it may, I think it is sufficiently apparent that the article of wages is also exaggerated, and that 500 viss must only be considered as the amount produce of working days, and not an average for every day in the year. The labour of the miners, as I have observed above, is altogether distinct from the oil drawers, and their pay proportioned to the hardships and risks they endure.

"Assuming therefore as data, the acknowledged profit of 1000 tecals per annum for each well, which we can hardly suppose exaggerated, as it would expose the proprietors to an additional tax, and the common wages of precarious employment in the country, that is one month with another, including holy days the year round, four and a quarter tecals per month as the pay of the oil drawers, which includes the two extremes of the question, it will make the average produce of each well per diem, 300 viss or 109,500 viss per annum, equal to 399,675 lbs. avoirdupois or tons 178,955 lbs.[1] or in liquid measure 793 hogsheads of sixty three gallons each, and as there are 520 wells registered by Government, the gross amount produce of the whole per annum will be 56,940,000 viss or 92,781 tons, 1,560 lbs. or 412,360 hogsheads, worth at the wells, at one and a quarter tecals per hundred viss, 711,750 tecals, or 889,737 sicca rupees.

"From the wells, the oil is carried, in small jars, by coolies, or on carts, to the river; where it is delivered to the merchant exporter at two tecals per hundred viss, the value being enhanced three-eighths by the expense and risk of portage, therefore the gross value or profit to the country of the whole, deducting five per cent. for wastage, may be stated at 1,081,860 tecals or 1,362,325 sicca rupees per annum, yielding a direct revenue to the king of 136,232 sicca rupees per annum, and perhaps thrice as much more before it reaches the consumer; besides the benefit the whole country must derive from the productive industry called into action by the constant employment of so large a capital on so gruff an article. There were between seventy and eighty boats, average burthen sixty tons each, loading oil at several wharves, and others constantly coming and going while I was there. A number of boats and men also find constant employment in providing the pots, etc., for the oil, and the extent of this single branch of internal commerce (for almost the whole is consumed in the country) will serve to give some insight into the internal commerce and resources of the country.

"At the wells the price of the oil is seven annas six pies per 112 lbs. avoirdupois; at the port of *Ranghong* it is sold at the average rate of three sicca rupees three annas six pies per cwt., or per hogshead of sixty three gallons weighing 504 lbs. fourteen rupees five annas eight pies, exclusive of the cask, or per *Bengal* buzar maund two rupees five annas eight pies, whereas the mustard seed, and other vegetable oils, sell at *Ranghong* at eleven rupees per buzar maund.

"To conclude, this oil is a genuine petroleum, possessing all the properties of coal tar, being, in fact, the self same thing, the only difference is, that nature elaborates in the bowels of the earth that for the *Burmhas*, for which *European* nations are obliged to the ingenuity of Lord Dundonald."

This report is a source of the most useful information about the oil-fields in those days. Most of the observations are correct, and have been confirmed by later observers. He went nearly into every detail; in fact, he deals so exhaustively with the subject that hardly anything remains to be added. There are of course some mistakes such as, when describing the timbering of the shafts, he says that the wooden square frames forming the casing of the pit are added at the top of the well, the whole gradually sinking as the well is deepened. A little reflection would have shown that this was impossible, the friction between the timber casing and the rocks being

[1] *Sic.* in orig.

so great that it would be quite impossible for the casing to sink by its own weight.

But, apart from small mistakes like this, Captain Cox's report is as accurate as possible, and, if it was not for the erroneous statement about the number of the wells and the rather mysterious statement of two towns of Yenangyoung, a lower and a centre one, separated a distance of 1½ hours of each other, the report would be a model of correctness.

It is impossible for me to find out what Captain Cox meant by the lower and the centre town of Rainanghong, the latter one is evidently the present Yenangyoung, but I cannot possibly make out what is meant by the lower town: perhaps it was Nyaunghla.

Captain Cox visited Bemè, as he distinctly states that there is another group of wells to the north-east of the one he visited. As Twingon lies to the north-east of Bemè oil-field, it is undoubtedly that it is the latter one he saw, although he greatly overrates the distance between both tracts.

He also greatly overestimates the number of wells. There cannot possibly have been 520 wells in 1797, for the reasons which I have pointed out before, if we do not accept the highly improbable theory that 200 wells have been so perfectly filled up again that no trace of them can now be discovered.

His description of the wells, their method of digging, and the extraction of the oil, is perfectly correct, and could have been written in our times.

The statements about the proprietary rights in the wells are the more interesting, as here for the first time the "families of hereditary well owners" a e mentioned, which have in these days, as twinzas and twinzayos, become of some importance.

The statements about duty, wages, and price of the oil are highly valuable, but the amount of the production must necessarily be greatly overrated, as it is based on the assumption of 520 wells each producing in the average 300 viss per day.

The next who wrote about the Yenangyoung oil-fields is Mr. Crawfurd, who visited the oil-fields in 1826. The following is the description he gives[1] :—

1826. Crawfurd.

"At three in the afternoon our whole party proceeded to the celebrated petroleum wells. Those which we visited cannot be further than three miles from the village, for we walked to them in forty minutes. The cart-road which leads to them is tolerably good, at least for a foot traveller. The wells occupy altogether a space of about sixteen square miles. The country here is a series of sand hills and ravines, — the latter, torrents after a fall of rain, as we now experienced, and the former either covered with a very thin soil, or altogether bare. The trees, which were rather more numerous than we looked for, did not rise beyond twenty feet in height. The surface gave no indications that we could detect of the existence of the petroleum. On the spot which we reached, there were eight or ten wells, and we examined one of the best. The shaft was of a square form, and its dimensions ahout four feet to a side. It was formed by sinking a frame of wood, composed of beams of the *Mimosa catechu*, which affords a durable timber. Our conductor, the son of the Myosugi, of the village, informed us that the wells were commonly from one hundred and forty to one hundred and sixty cubits deep, and that their greatest depth in any case was two hundred. He informed us that the one we were examining was the private property of his father — that it was considered very productive, and that its exact depth was one hundred and forty cubits. We measured it with a good lead line, and ascertained its depth to be two hundred and ten feet ; thus corresponding exactly with the report of our conductor—a matter which we did not look for, considering the extraordinary carelessness of the Burmans in all matters of this description. A pot of the oil was taken up, and a good thermometer being immediately plunged into it, indicated a temperature of ninety degrees. That of the air, when we left the ship an hour before, was eighty two degrees. To make the experiment perfectly accurate, we ought to have brought a second thermometer along with us; but this was neglected. We looked into one or two of the wells, and could discern the bottom. The liquid seemed as if boiling; but whether from the omission of the gaseous fluids, or simply from the escape of the oil itself from the ground, we had no means of determining. The formation, where the wells are sunk, consisted of sand, lose sandstone, and blue clay. When a well is dug to a considerable extent, the labourers informed us that brown coal was occasionally found. Unfortunately we could obtain no specimens of this mineral on the spot, but I afterwards obtained some good ones in the village. The petroleum itself, when first taken out of the well, is of a thin watery consistence, but thickens by keeping, and in the cool weather coagulates. Its colour, at all times, is a dirty green, not much unlike that of stagnant water. It has a pungent aromatic odour, offensive to most people. The wells are worked by the simplest contrivance imaginable. There is over each well a cross beam, supported by two rude stanchions. At the

[1] Journal of an Embassy from the Governor-General of India to the Court of Ava in 1827 4° London, 1829, p. p. 53—56, 427, and 445.

centre of the cross-beam, and embracing it, is a hollow revolving cylinder, with a channel to receive a drag-rope, to which is appended a common earthen pot that is let down into the well, and brought up full by the assistance of two persons pulling the rope down an inclined plane by the side of the well. The contents of the pot are deposited for the time in a cistern. Two persons are employed in raising the oil, making the whole number of persons engaged on each well, only four. The oil is carried to the village or put in carts drawn by a pair of bullocks, each cart conveying from 10 to 14 pots of 10 viss each, or from 265 to 371 pounds avoirdupois of the commodity. The proprietors store the oil in their houses at the village, and there vend it to the exporters. The price, according to the demand, varies from four tecals of flowered silver, to six tecals per 1000 viss, which is from five pence to seven pence half penny per cwt. The carriage of so bulky a commodity, and the breakage to which the pots are so liable, enhance the price, in the most distant parts to which the article is transported, to fifty tecals per 1000 viss.......

" Petroleum is used by the Burmans for the purpose of burning in lamps, and smearing timber to protect it against insects.......The quantity exported to foreign parts is a mere trifle, not worth noticing. It is considered that a consumption of thirty viss per annum, for each family of five and a half persons, is a moderate average.......

" ...... I made such enquiry into the nature of the trade as my short stay would admit. The number of boats waiting for cargoes of oil was correctly taken, and found to amount to one hundred and eighty three, of very various sizes, some carrying only one thousand viss, others fourteen thousand. According to the Burmese, whom I consulted, the average burthen of the vessels employed in this traffic, was considered to be about four thousand viss. The number now mentioned is not considered unusual; and it has been reckoned that, one with another, they complete their cargoes in fifteen days; they are therefore renewed 24 times in the course of the year; and the exportation of oil according to this estimate will be 17,568,000 viss.......

" Of the actual produce of the wells, we received accounts not easily reconcilable to each other.......The daily produce of the wells was stated, according to goodness, to vary from thirty to five hundred, the average, giving about two hundred and thirty five viss; and the number of wells was sometimes given as low as fifty, and sometimes as high as four hundred. The average made about two hundred; and considering that they are spread over sixteen square miles, as well as that the oil is well known to be a very general article of consumption throughout the country, I do not think this number exaggerated."......

"The celebrated petroleum wells afford, as I ascertained at Ava, a revenue to the King or his officers. The wells are private property, and belong hereditarily to about thirty-two individuals. A duty of five parts in one hundred is levied upon the petroleum as it comes from the wells, and the amonnt realized upon it is said to be twenty-five thousand tecals per annum. No less than twenty thousand of this goes to contractors, collectors, or public officers; and the share of the state, or five thousand, was assigned during our visit as a pension of one of the Queens" ...... (page 427).

"From the more accurate information which I obtained at Ava, it appears that the produce of these may be estimated at the highest, in round numbers, at about twenty-two millions of viss, each of $3\frac{65}{100}$ pounds, avoirdupois. This estimate is formed from the report of the Myo-Thuggi, who rents the tax on the wells, which is five in hundred. His annual collection is 25,000 tecals, and he estimated or conjectured that he lost by smuggling about 8,000, making the total 33,000. The value of the whole produce, therefore, is 660,000 tecals. The value of the oil on the spot is reckoned at three tecals per hundred viss, and consequently its amount will be as above stated."

The statement in this account that the wells extend over an area of 16 square miles is curious, seeing that, allowing a very liberal margin, the oil-fields cover an area of only 343 acres, or a little over half a square mile. The estimate of the outturn can hardly be considered of much value, having been arrived at in rather a summary way, particularly as regards the export of oil from Yenangyoung. In fact, Crawfurd's reports contain less information about the condition of the Burmese oil-fields, than Captain Cox's description, although the latter had been made 30 years previously.

1835, Captain Hannay.

In 1835 Captain Hannay visited the oil-fields. Unfortunately I have no access to his manuscript, but his statement of an annual production of 93,000 tons seems exaggerated.

Captain McLeod, 1838.

It is a pity that Captain McLeod's manuscript on the oil-fields, which he visited in 1838, formerly kept in the Foreign Office, and quoted by Captain H. Yule, has never been published, as it appears to have contained some valuable information. Captain McLeod states the number of wells as not higher than 160, which for various reasons I believe to be nearly correct; but he certainly underestimates the average yield per well, namely, 36 viss per day. Even now, although the fields are not so productive, the average is higher, and we may conclude that it was still higher 52 years ago.

The next description added much to a knowledge of the oil-fields.

Captain Yule, 1855.

It is contained in Captain (afterwards Sir Henry) Yule's account of the Mission to Ava[1] in 1855, in which two members of the Mission, Captain Yule and Dr. Oldham, give their observations, and as they are of great importance, I give both accounts in extenso. The following is Captain Yule's description :—

"We started early to visit the earth-oil wells, or mines, as they might be called....... Our road wound about among the ravines and up the steep sides of the rotten sandstone hills, till, about three miles from the town, we came upon the plateau on which the principal wells are situated. It is an irregular table with a gently rising surface, forming a sort of peninsula among the ravines.

"The wells are frequent along its upper surface, and on the sides and spurs of the ravines which bound it on the north and south-east. They are said to be about a hundred in number, but of these some are exhausted or not worked. The depth of the wells appeared to vary in tolerable proportion with the height of the well-mouth above the river level, but an inspection of the lowest, situated near the bottoms of the ravines, enabled us to ascertain that all were sunk a good deal below the level of the ravine bottoms which bounded the plateau. Those that we measured (by pacing the length of the rope used) on the top of the plateau were 180 feet, 190 feet, and 270 feet in depth to the oil. One was said to be 20 cubits deeper than this last, which would give a depth of about 306 feet.

"As far as we could judge, the area within which these wells stand does not exceed half a square mile. The wells are in some places pretty close together; less, that is to say, than a hundred feet apart. They are all exactly alike in appearance; rectangular orifices about four and a-half feet by three and a-half, and lined with horizontal timbers the whole way down. The oil appears to be found in a stratum of impure lignite, with a good deal of sulphur. In one of the valleys we saw a stratum of this out-cropping, with the oil oozing between the laminæ. Doubtless, it was in this way originally discovered; some Burman, with a large inductive faculty, having been led to sink a shaft from above.

"A rude windlass, mounted on the trunk of a tree, laid across two forked stems, is all the machinery used. An earthen pot is let down and filled, and then a man or woman walks down the slope of the hill with the rope. There is another group of oil-wells in a valley about a mile to the southward.

"The petroleum from these pits is very generally used as a lamp-oil all over Burma. It is also used largely on the wood-work and planking of houses, as a preservative from insects, and for several minor purposes, as a liniment, and even a medicine taken internally. The Chinese Geography, translated in Thevenot's *Voyages curieux*, says that it is a sovereign remedy for the itch, which its sulphurous affinities render highly probable. There is now a considerable export of the

[1] A narrative of the Mission sent by the Governor-General of India to the Court of Ava in 1855, with notices of the country, government, and people. General report by Captain H. Yule; Geological Report by Dr. Oldham: 4° London 1858, pages 19—22.

article from Rangoon to England, and one of the Rangoon houses had a European agent residing on the spot. The demand in England is, I believe, for use to some extent as a lubricating oil, but it is also employed by Price's Company at Lambeth in the manufacture of patent candles, and has been found to yield several valuable products. It has sold in the London market at from £40 to £45 a ton.

"The oil itself looks like thin treacle of a greenish colour, and the smell is not unpleasant in the open air, and in moderate strength.

"The northern group of wells contains, as well as could be learned, about 80 wells now yielding oil. The southern group contains about 50, which yield an inferior kind of oil mixed with water. At either place there are many exhausted wells. Each group occupies a space of about half a square mile or somewhat less. There appears to be no record or tradition as to the original discovery of the petroleum, or as to the lapse of time since it was first worked. The wells are private property, the ground they occupy being owned by 23 families, inhabitants of Yenangyoung, and the representatives, it is believed, of those who first discovered and worked the petroleum. Among these is the hereditary Myo-thoogyee of the place, who holds at present the office of *Myit-tsin-woon* or chief magistrate of the great river. They do not allow any stranger to dig a well; and although a respectable owner stated that they had no written grant or confirmation of their exclusive privilege, yet it is upheld by the local Burmese authorities, and apparently they have sufficient influence to prevent any wells being dug by interlopers in the vicinity of their groups or clusters of wells. But, independently of the influence they thus exert to prevent any interference with their privileges and profits, the great expense in the present dearth of capital, and the uncertainty of return, prevents any one trying seriously to compete with them. The twenty-three proprietors constitute a kind of corporate body, as regards their joint interests in the land, but possess individual property in their own wells. When once a well has been dug, no one else is allowed to dig within 30 cubits of it. No proprietor is allowed to sell or mortgage his well to anyone not a proprietor. They mortgage them among themselves. Formerly they intermarried among themselves only; but, latterly, an old and respectable proprietor informed Major Phayre, this custom had been broken through by the 'young people.'

"The cost of digging a well 150 cubits deep was said to be 1,500 to 2,000 tecals, sometimes even more; and after all, the money might be thrown away, as a well dug within a few yards of others yielding a good supply often proves a failure. The work of excavation becomes dangerous as the oily stratum is approached, and frequently the diggers become senseless from the exhalations. This also happens in wells that have been long worked. 'If a man is brought up to the surface with occasionally his tongue hanging out,' said one of our informants, 'it is a hopeless case. If his tongue is not hanging out, he can be brought round by hand-rubbing and kneading his body all over.'

"The yield of the wells varies greatly. Some afford no more than five or six viss, whilst others give 700, 1,000, and even, it is said, 1,500 daily. From all that we could learn, the average yield of the wells in the northern group to be 40 viss. Generally the supply from a well deteriorates the longer it is worked. And if it be allowed to be fallow for a time, it is said that the yield is found to be diminished on the recommencement of the work.

"The oil is described by the people as gushing like a fountain from openings in the earth. It accumulates in the well during the afternoon and night, and is drawn off in the morning. The proprietors have the oil conveyed to the river side in carts loaded with earthen pots containing ten viss each.

"The ordinary price of the article used to be one tecal the hundred viss, or about sixteen shillings a ton. Lately, in consequence of the demand from Rangoon, it has risen to about thirty-five shillings a ton.

"As to the amount of revenue derived by the King from the petroleum we found it difficult to get definite information. One intelligent proprietor, who was a *Myo-ok* of the town, stated that out of the 27,000 viss, which formed the whole monthly yield of his wells, 9,000 went in payment to the work-people, 1,000 to the King, and 1,000 to the lord of the district.

"It is an object of some interest to endeavour to ascertain the approximate amount of petroleum yield by these wells. There was not time to make very minute enquiries on this head, not to mention that questioning closely every proprietor might have given umbrage to the Burmese officers, and excited their jealousy. From the information derived, however, from the proprietors who came to the Envoy, and from general enquiries by other members of the Mission, it appears that there are in the northern group of wells about 80 yielding oil. This would give, at the daily average of 220 viss from each well, an annual amount of 6,424,000 viss drawn from the northern group.

"The 50 wells of the southern group are assumed to yield on the average 40 viss each daily. Their yield, therefore, annually, would be 730,000 viss, making a total quantity of 7,154,000 viss annually, equal to about 11,690 tons. This is very nearly what the Myo-ok stated the produce to be, and it was, in all probability, about the truth."

Excepting some small inaccuracies this account is undoubtedly very correct, and it is the more important, as it gives for the first time definite information about the rights and customs of the 23 twinzayo families. In fact, Captain Yule has given in this short description all that has come out during the long enquiries held lately about the customs and rights of the twinzayos. His evidence is the more important, because it is not influenced by the various interests of the present times, which lead the Burman to make only such statements as seem to be most profitable to himself. In Captain Yule's description we find the same difficulty which we encountered in previous accounts. It is difficult to say which of the two oil-fields he visited. The illustrative view of the oil-field at Yenangyoung accompanying the description is difficult to recognize. It was only quite accidentally that I hit on the very spot from which the view was taken; it lies a little to the south of well No. 594 (Bemè) on the top of the hill, the spectator looking towards west, that is to say, towards Yenangyoung. In this view the pagoda to right represents the big pagoda just west of Bemè, the village in the centre is Bemè and the hill right in the centre of the back ground is Minlindoung, the highest hill in this part of the country. There is therefore no doubt that the view of the "oil-wells at Yenangyoung" represents the view of the southern part of the Bemè oil-tract, seen from the east; and we may therefore assume that the party certainly visited Bemè, but whether they also went to Twingôn is difficult to say. From the above description one might be led to believe that Twingôn only was visited, but the picture of the landscape agrees with the natural aspect of the Bemè tract. As regards the number of wells, Captain Yule states in the beginning of the description that they are "about a hundred in number," but whether this applies to the total or only to the wells of a single group cannot be made out. He afterwards states that there are 80 wells in the northern and 50 in the southern group, that is to say, 130 in the aggregate. His estimate of the annual production seems to be fairly correct, although it is astonishing that 36 years ago the average daily production of the Bemè wells should not have been more than 40 viss, while in 1888 it was 50·77 viss.

I now give Dr. Oldham's account of the oil-fields (pp. 316—318):

"This may be a suitable place to make a few remarks on the abundance of the supply of the valuable product, earth-oil or petroleum. No absolute section of any of these wells could be obtained. In all cases they are carefully timbered up as the sinking proceeds, and this is continued from the top to the very bottom, so that no examination of the sides of a well or pit could be made. The soft and yielding nature of the materials through which the sinkings are made renders this necessary. And where they have not been successful in their adventure, or when the well or pit seems to be exhausted, all the timbering is removed again, and the whole allowed to fall in.

"According to the natives, after passing through the sandstones and shales, visible at the surface and in the ravines adjoining, they sink through what they call a 'black soil' or 'black rock.'

"This, they say, is about 10 feet in thickness, and is obviously their name for the dark bluish-grey or blackish shales, or clunchy clay.

"Under this they cut through a yellow soil, and from this they state the petroleum issues. Between the black and the yellow rocks there is commonly, although not always, a greenish bed, oily, and strongly impregnated with petroleum; and this, in all probability, is nothing but the ordinary shaly clay, charged with oil.

"The 'yellow soil' I fancy to be clayey beds, from which, or on which, sulphur has been segregated or thrown out, as an efflorescence.

"The wells are put down vertically. They are square or rectangular in section, and about four feet six inches on each side.

"Over each well a cross beam, supported on staunchions at either side, is placed, and on the centre of this is a small wooden drum or cylinder, over which the rope used in hauling up the oil passes.

"A common earthenware gurrah, or pot, is attached to the rope, and, being lowered, is allowed partially to fill by sinking into the oil below, and is then drawn up by a man or men, who walk with the rope down an inclined plane at the side of the well. The oil thus raised is poured into another pot, or into a small basin excavated close to the well mouth, and from this is packed into gurrahs for conveyance to the village for shipment. Each cart conveys from 10 to 12 gurrahs, each gurrah holding about 10 viss of oil, or, on the average, 100 viss (365 lbs.) on each cart. The oil is raised only in the morning, and, the quantity which each well is known by experience to give having been raised, the work then ceases, and the oil is allowed to accumulate during twenty-four hours. On the following morning the process is repeated. The petroleum, when first extracted, has in mass a peculiar yellowish green colour, is watery more than oily, and of the consistence of ordinary cream.

"From some of these wells 400 viss (1,416 lbs.) are extracted daily; one which we saw had, according to the statements of the natives, yielded this large amount daily for some months, and from it this quantity had that morning been taken. Others, again, only yielded 60 viss, or less; while not unfrequently, after large expenditure in sinking and reaching what they consider the proper soil of the petroleum, the well will prove a failure and yield none. The wells[1] are in two principal groups, as mentioned above, which are nearly two miles apart. They have been sunk indifferently on the slopes of the deep ravines, and from the level plateau on top. They do not occur in any particular line or direction; there is nothing to point to the occurrence of any fault or disturbance, along the line of which the petroleum might issue, and the varying depths of the wells themselves, according to their position (those on the top of the plateau being, in all cases, deeper than those on the slope of the hillside, and this, approximately, in the same ratio as the surface of the ground is higher in one place than in the other), indicate a tolerable horizontality in the source of supply. This is a question of considerable importance; for if it be the case that one bed or layer of peculiar mineral character is the source of the petroleum, the

[1] One of the wells on the top of the plateau has a depth of 180 cubits (royal cubits=22 inches) and they range from 140 to 180, or from 250 to 330 feet; while those on the slope of the hill vary from 100 to 60 cubits, according to position, or from 180 to 110 feet, while the bed of the stream or watercourse is from 120 to 130 feet below the level of the plateau.

probability, nay, I would say, the certainty is, that the supply must be gradually diminishing. I could not learn that the number of the wells has been increased lately, while the demand for the product has increased more than fourfold, and is daily increasing. These facts are sufficient to account fully for the greatly enhanced price of the oil. The ordinary price of the petroleum, previously to the British annexation of Pegu, was at the village of Yenangyoung, from 10 annas to 14 annas per 100 viss. It has since increased from 1 rupee to 1-8 ; and an agent for a mercantile house at Rangoon, who was there at the time of our visit, stated that he had to pay even so much as 2 rupees 4 annas for 100 viss. At Rangoon, the price used to be from 2 rupees to 2-8 ; it is now never less than 5 rupees, and has been so high as 25 rupees per 100 viss. An export duty of 10 per cent is now charged on this oil. The Burmese Government also charge 3 per cent. Under the former system, it is stated that the charges, including the established douceurs to brokers, etc., were not less. In number, the wells were stated by the head-man of the village to be about 200 ; others said 100. *They certainly do not exceed in number 200.* The well which yielded 400 viss per diem was shown to us as a remarkable one ; others were acknowledged to yield only 60 viss ; and I think there was a general tendency in our informants to swell the amount rather than diminish it. The average yield of the whole, therefore, must be much less than it was estimated to be by Mr. Crawfurd. Very careful inquiries convinced me that the average could not be more than 180 viss from each well per diem. This would give (allowing that there may be 200 wells at work, which I consider beyond the truth) a total of 36,000 viss per day. If we take the working days at 300 in the year (which again is, I think, above the truth, considering the number of holy days, etc., in which a Burman revels), this would give a total produce annually of 10,800,000 viss. Deducting from this 1-20th as an allowance for waste, breakage of gurrahs, loss of boats, etc., we should have 10,800,000—540,000 = 10,260,000, *i.e.*, ten millions and one-quarter viss as the net available produce per annum.

" Another mode of arriving at the annual produce is to take the number of carts employed daily in the conveying of the oil to the point of shipment, and multiply this by the average load of each. Now we could not ascertain that there were more than 150 carts so engaged, if so many. The average load of each of these is 100 viss, and taking, as before, 300 days' work, we should have 100 × 150 × 300 only 4,500,000 viss annually, not one-half of what was stated to us.

" We have above calculated from the number of wells, as given by the Burmese themselves ; I am convinced, however, that the number given is above the fact. I could not see any reason to believe that in the larger group there were more than 80 and in the smaller or southern group more than 50 wells actually yielding petroleum ; the amount obtained from the wells of the southern group is also much less than that from the northern wells. It is also inferior in quality. In my view, either the produce has diminished most materially since Mr. Crawfurd's visit, or he very much over-estimated it from erroneous data. I fancy that both these causes have combined to render his estimate too high at present.

" These wells are, each singly, or a group of a few wells close together, the property of different individuals. In some cases they are a source of large and continuous profit; in others unsuccessful trials, which are not unfrequent, absorb all the profit, and even ruin the adventurer; one of these pits costs from 1,500 to 1,800 Rs.—a large sum for such men to risk. Each family or individual has certain tolerably well-acknowledged limits, within which their rights of property are confined, but questions of boundary are a source of constant litigation; the opening of a successful well close to the supposed boundary generally leading to a discussion of these limits, and to long and angry disputes."

Dr. Oldham's description is less exhaustive than that of Yule; the chief point of interest is that he arrives at two widely different estimates of the annual production; his first estimate is decidedly too high, as he himself admits that the number of productive wells is certainly not higher than 130 in the aggregate. The statements about the twinzayo families are rather vague.

The chief interest of both these reports lies in the fact that both Yule and Oldham arrive at the conclusion that the number of productive wells in 1855 was certainly not higher than 130.

I cannot trace any notes on the oil-fields in Upper Burma between 1855 and 1873, when Captain (now Colonel) Strover submitted a highly interesting and valuable memorandum on the metals and minerals of Burma which was published in the *Gazette of India*.[1] This is what Colonel Strover says about the oil-fields:

"There are at present about 150 wells worked at Yenangyoung; the quantity of oil estimated as deliverable from these wells is 15,000 viss daily, of which 10,000 viss is taken by the contractor who supplies British Burma and 5,000 viss by the contractor who supplies Upper Burma. The yield of the wells is estimated yearly by officials sent down to Yenangyoung by His Majesty, and the Royal revenue is calculated at Rs. 7-8-0 per 100 viss and realizes four lakhs of rupees per annum. The total yield of these wells is 6,000,000 viss per annum or 9,375 tons. At Pagan there are about 50 wells: they yield daily 1,500 viss of oil, which the earth-oil contractors, at present the Lay-myo-woon, and one Maung Tsanwah, are allowed to purchase. The total estimated output per annum is 6,600,000 viss to 10,312½ tons."

Colonel Strover's distinct statements are the more valuable as they describe the condition of the oil-field just previous to a great rise in the number of wells. Pagan (or the oil-field of Yenangyat) is here mentioned for the first time.

[1] G. A. Strover. Memorandum on the metals and minerals of Upper Burma: *Gazette of India Supplement* (1873); reprinted in *Geol. Mag.*, 1st decade X, pp. 356—361 (1873).

Dr. Friedländer visited the oil-fields in 1874, and his notes, "The Country of Earth-oil in Upper Burma," were published in the *Burma Gazette* of the same year.[1] His description is very vague and does not come up to the mark of any of his predecessors. The only fact worth mentioning which he records is the existence of a rude pipe-line to convey the oil from the fields to the river. Dr. Friedländer says:

"Worth mentioning here is also the oleiduct now in course of construction at Yenangchoung, and a decided improvement upon the old mode of transport by chatties in carts. Wholly made out of bamboo, supported by wood stages (the inside lacquered), it runs with a gentle slope from the wells down to the river bank: a great loss of oil by evaporation is inevitable."

The existence of this pipe-line has been confirmed by the statements of several natives, but they all added that the loss by leakage was so great that they gave it up at once. The earth-oil wells (of Yenangyoung) are situated on a plateau, says Dr. Friedländer, five miles from the river near the village of Tôngong (Twingon). The number of wells are said to be 450.

At Pagan (namely, Yenangyat) there are 70 wells in working, most of them are new and they are adding daily others to their number; the depth of the wells is from 60 to 80 feet.

The late Dr. Romanes, who visited the oil-fields of Yenangyoung in 1884, reports as follows[2]:—

"The oil-wells of Yenangyoung are situated on the banks of the creek that flows into the Irrawaddy at that place. There are two groups, the smaller about two miles east of the town, the other about three miles north-east.

"The country is a tableland intersected by ravines, the beds of torrents flowing into the creek. The surface is covered with gravel and blocks of fossil wood. Below is a great thickness of a friable sandstone, below this again a blue shale alternating with beds of sand. It is in the sand that the oil is found.

"The wells are sunk indifferently on the sides of the ravines and on the tops of the hills. The strata appear to dip generally towards the west with many folds

[1] Dr. H. Friedländer. The country of earth-oil in Upper Burma. *Supplement to the British Burma Gazette*, Feb. 14th, 1874, pp. 45—48.

[2] R. Romanes. Report on the Yenanchoung Oil-Wells. Flsc. Pam. Rangoon, 1884.

and contortions, and the ravines run in a westerly direction. Hence a well at the head of a ravine, on the top of the hill, may reach the oil-bearing stratum as soon as one at the bottom. We saw a well being dug at the top of the hill. They had reached a depth of 135 feet. They were cutting through a hard blue shale full of cracks filled up with sand. The sand was wet with oil, but not enough to drain out. Another well, about 50 yards off in the ravine, was 250 feet deep. It was 40 years old, oil had been reached at 160 feet, and it had been gradually deepened to its present depth as the stratum of shale had been exhausted of oil. We saw some fragments of rock that had just been brought up. It was this same hard blue shale with cracks filled up with sand that we had seen at the other well. Going down the ravine I found a stratum of this oil-bearing rock cropping up, but apparently higher than that into which the wells were sunk.

"This was the only well we saw at work, the others were stopped for the day. It gave 150 viss daily, and might give more were there means of carrying away the oil. The oil is raised in earthen pots shaped like a gourd holding about 8 to 10 viss, from these it is decanted into larger pots of the same shape holding about 15 viss. Ten or twelve of these make a cartload estimated at 150 viss = about 5 cwt. The work of raising the oil was performed by a labourer and his wife, who were paid 8 annas per diem, 4 annas each. They work in connection with a carter who is paid Re. 1 for himself and a pair of bullocks making one trip a day to the river shore, whence the oil is carried in bulk in boats to the steamers. The capacity of the boats is said to be about 25 tons of oil.

"The method of raising the oil is very rude. Two forked branches set upright carry a horizontal beam bearing a roller over which passes the rope. The labourer takes the end of the rope and runs down hill with it and holds it while his companion runs down with another length, and so on. While the last length of rope is being drawn out, one of the men is waiting at the mouth of the pit to exchange the full pot for an empty one.

"It is impossible to say what the real maximum yield may be. Many of the wells are not worked; some of them are exhausted. We found that there were 130 cartloads brought from the great wells,[1] and this represented the accumulation of five days. Dr Oldham, thirty years ago, was told that the yield was 150 carts daily. If the wells are worked to their utmost now, unless Dr. Oldham was misinformed, the productiveness has greatly fallen off.

"We were told that two wells had been sunk at a point to the south-west of the smaller wells on the other side of the watershed; that oil had been obtained, but it was mixed with water, and the wells had been abandoned. I think it very probable that oil-bearing strata may be found all over that strange barren table land, of which Yenanchoung is the centre.

"The rock formation seems to be much more recent than that in which we find the petroleum of Yenantaung in the Myanaung district and the coal of Ôkpo.

"I found many fragments of fossil bones but none perfect. The ferruginous concretions referred to by Dr. Oldham turn out on analysis to be principally oxide of manganese; some calcaceous-looking nodules are carbonate of magnesium.

"The curious concretions which Dr. Oldham found on the shore are really cases of the roots of plants and of very recent formation. I found many *in situ*

[1] *i.e.*, Twingon, F. N.

with the central vascular part of the root still remaining. Those on the shore have no doubt fallen from the top of the cliff as the river has washed it away.

" A fossil tree was found with the stumps of the roots and branches and the texture of the wood so well preserved that it seems possible to determine the nature of the wood.

" The present vegetation consists of *acacias* and *euphorbias*. A thorny shrub of the genus *zizyphus* is not uncommon ; it is used for fencing the cattle pastures. The only crop is maize. Jaggery made from palms is brought from the interior."

1886 Burmese minister.

Information about the sale of oil during the period 1879 to 1881 is contained in a letter dated the 22nd July 1886 written by one of the late Burmese ministers and addressed to the Chief Commissioner of Burma.[1] It contains interesting data about the number of wells, the production and the way in which the King of Burma disposed of the oil. As this letter is the only document relating to the above period, and as the statements are apparently reliable, I give here extracts from it :—

" It was customary to make over the oil obtained from the Royal wells as well as from those of the twinzas to the farmer of the year who paid a certain amount of royalty to the Government. The amount of such royalty was determined by an estimate prepared beforehand. Thus from the year 1241 to 1243 (1879 to 1881) the following estimate was made :—

	Viss.
Monthly yield	400,000

" This was distributed in the following way :—

	Viss.	Value in Rs.
(*a*) For Royal purposes	10,000	?
(*b*) Brought up the river at R25 per 100 viss . .	120,000	30,000
(*c*) Taken down the river at R15 per 100 viss . .	270,000	40,500
Total	400,000	70,500

" The total of proceeds were therefore estimated at R70,000 per month.

" The actual expenditure was :—

	R
(*a*) Paid to twinzas for the oil at R1-8-0 per 100 viss . . .	6,000
(*b*) On account of boat-hire R2-8-0 per 100 viss	10,000
Total	16,000

I Total of proceeds	70,000
II Total of expenditure	16,000
Balance	54,000

[1] Dr. Fritz Noetling. *Report on the Petroleum industry in Upper Burma from the end of the last century up to the beginning of 1891*, pp. 14-15, Rangoon, 1892.

"Thus the farmer paid a monthly royalty of R50,000 during these years. Since 1243 (1881) the demand for earth-oil was diminished and the whole of the yield could not be bought up. The estimate was :—

	Viss.
(*a*) For Royal purposes	10,000
(*b*) Brought up the river	90,000
Brought down the river	160,000
Total	260,000

"Proceeds of sale R34,700.

"Made up of R23,400 value of the oil brought up and sold at R26 per 100 viss plus R11,200, the value of the oil taken down and sold at R7 per 100 viss.

"Expenditure—

	R
(*a*) Paid for the oil R1-8-0 per 100 viss	3,900
(*b*) Boat-hire at R2 per 100 viss	5,200
Total	9,100

I Total of proceeds	34,700
II Total of expenditure	9,100
Balance	25,600

"Thus the farmer paid to the Government R2,500 as a monthly royalty. Subsequently, in May 1885, the royalty was reduced to R20,000. The twinzas were exempted from the thathameda or capitation-tax on account of their services rendered to the Government."

The following table was appended to the letter :—

	Yenangyoung.				Pagan.				Total.			
	Number of wells.	Unproductive wells.	Productive wells.	Approximate monthly yield in viss.	Number of wells.	Unproductive wells.	Productive wells.	Approximate monthly yield in viss.	Number of wells.	Unproductive wells.	Productive wells.	Approximate monthly yield in viss.
Royal wells . .	138	72	66	26,000	38	23	15	8,000	176	95	81	34,000
Wells belonging to twinzas.	198	...	198	360,000	*	*	*	2,000	198	...	198	362,000
Total .	336	72	264	386,000	38	23	15	10,000	374	95	279	396,000

* Number not stated.

CHAPTER II.—THE OCCURRENCE OF PETROLEUM IN THE DISTRICTS OF PROME AND THAYETMYO.

Although not quite falling within the scope of this memoir, it will be useful, for the sake of completeness, to mention the occurrences of petroleum in the above districts. I paid a flying visit to Padouk-bin and Banbyin early in the rainy season of 1892, but partly on account of the rains, partly on account of the dense jungle, I was not able to see much for myself, and, as my time was limited, I could not examine the geological features of these localities as well as of others. I follow, therefore, chiefly Mr. Theobald's description,[1] adding remarks or observations of my own.

1.—GEOGRAPHICAL POSITION.

Mr. Theobald mentions the following localities :—

1. Yenandoung, 12 miles south-west of Myanoung, Lat. 18°9′, Long. 95° 12.′
2. Padouk-bin, Lat. 19°21′, Long. 95°11′, about seven miles west by north from Thayetmyo.
3. Banbyin, Lat. 19°21′ Long. 95°10′. about 11 miles west-north-west of Thayetmyo.
4. Toungboji, about 11½ miles west from Prome Pagoda, about Lat. 18°20′, Long. 95°4′.

As already noticed by Mr. Theobald, all these localities are situated on the western bank of the Irawadi river, and he mentions no occurrences of petroleum within the area of the Pegu Yoma, that is to say, on the eastern side of the Irawadi.

2.—GEOLOGICAL FEATURES.

Mr. Theobald states that all the localities are situated among the nummulitic rocks or the still newer tertiaries. I am unable to verify this statement with regard to the 1st and 4th locality, but as regards Padouk-bin and Banbyin, I can say, from personal experience, that the series there developed must be considered to belong to the Pegu division. Mr. Theobald states that at Padouk-bin the rocks are "soft, earthy bluish sandstones and shales of the newer tertiaries." From this we may conclude that he does not consider them as eocene.

[1] Mem. Geol. Surv. Ind., X, 346.

With regard to the second locality, Mr. Theobald is a little more explicit, stating that "the country consists of beds of shale and sandstone, occupying a high position in the newer tertiary group, and probably not far removed geologically from the horizon of the bed at Padouk-bin."

From this we may conclude that Mr. Theobald opines, that the petroliferous beds of both localities belong to his Pegu group, holding a high position in the series. Mr. Theobald concludes his remarks about the Banbyin oil locality by stating that the shales contain certain fossils of the ordinary Miocene types: *Ostrea*, *Pecten* (2 species), *Conus*, *Cypræa*, *Arca*, *Solen*, *Turilella*, crab's claws, shark's teeth, etc.

I have unfortunately not found any fossils myself at the last-named place, nor have I succeeded in finding the above-named fossils among Mr. Theobald's collections from Lower Burma, but I have no doubt that the species will agree with those described by me from Minbu or Yenangyat.

This view, together with Mr. Theobald's statement that the petroliferous beds hold a "*high position*" in the series, prove that the geological horizon of these beds must be nearly the same as that of the petroliferous sands of Upper Burma, *viz.*, the upper part of the lower miocene or Prome stage. With regard to the 4th locality, of which I have no personal experience, Mr. Theobald simply states that it is situated within the area of the Nummulitic rocks, without giving any further evidence for his statement. It is *à priori* not impossible that petroleum should occur in the eocene rocks, but so far it has everywhere in Upper Burma been found in beds of miocene age. Before, therefore, accepting the eocene age of the Toung-boji petroleum, I think the matter requires further confirmation.

As regards the first locality near Myanoung, the description of the strata proves clearly that they belong to Mr. Theobald's Pegu group; in other words, that they are of miocene age.

3.—STRATIGRAPHICAL FEATURES.

Little or nothing is known about the structural conditions under which the petroleum occurs; Mr. Theobald simply states that the strata are "rolling and dipping at various angles," but the diagram he gives of the occurrence of petroleum at Padouk-bin clearly proves that it occurs on the crest of an unsymmetrical anticline. As far as I am able to judge, both occurrences of Padouk-bin as well as Banbyin are situated on an anticline running north-west to south-east.

With regard to the other two localities, I am unable to say anything definite, but further researches will probably prove that they are situated on anticlinal arches.

4.—ECONOMIC VALUE.

The above-named localities have hitherto not given rise to any industrial undertaking; even the natives after some attempts have entirely abandoned their wells, which at the time when I visited these localities were in a very dilapidated condition.

The Burma Oil Company had several deep wells drilled at Padouk-bin before they commenced to bore at Yenangyoung. Unfortunately there were no boring registers kept, or if there were any, they have been lost. As far as I could ascertain the wells reached a considerable depth, but no petroleum was found, and the Company eventually abandoned this particular spot as unprofitable.

Although it might be rash to entirely condemn the occurrences of petroleum in Lower Burma as insignificant, when nothing more is obtainable than such meagre information, my personal opinion is that it is very unlikely that these small occurrences indicate a larger quantity of petroleum in greater depths. This much has been proved by the deep borings at Padouk-bin. It may be that, when the indications are followed up, richer oilsands will be discovered, but it seems questionable whether they would be worth the large expenditure incurred.

CHAPTER III.—THE OCCURRENCE OF PETROLEUM NEAR MINBU.

1.—GEOGRAPHICAL POSITION AND PHYSICAL GEOGRAPHY.

The village of Minbu is situated at Lat. 20°10′, Long. 94°56′ on the right bank of the Irawadi about 423 miles above Rangoon, at the northern end of a low hill range. The vast alluvial plain of the Mon river extends to north of Minbu; to the south and west of it is a low hilly country, which comes right up to the bank of the river. Petroleum has been found at different places in the neighbourhood of Minbu, and there are indications at the southern slope of Leit-taung that petroleum was formerly gathered in shallow pits. These are now entirely abandoned and dried up.

The next place where petroleum oozes out on the surface is around the Nagabwet-taung or mud volcanoes, on the northern bank of the Sabwet-choung, a small feeder of the Irawadi river.

About five miles in a straight line, further the south, in a small stream between the villages of Palangon and Nandawgon is a third locality where there are some surface indications.

But nowhere has an attempt been made to extract the oil from the deeper beds, although the petroleum was gathered to a small extent from the surface of natural springs. It is difficult to say why the Burmans, who have followed up the surface indications at Yenangyoung and Yenangyat, have never attempted to exploit the petroliferous beds of Minbu.

2.—GEOLOGICAL FEATURES.

A.—The Pliocene or Irawadi series. Lithological and palæontological characters.

This division consists chiefly of yellowish sandstones of various degrees of hardness, with subordinate coarse conglomerates, which are always more or less ferruginous; globular or flat concretions of hard, quartzitic sandstone are common.

As regards the palæontological characters I am unable to say more than a few words, because fossils are somewhat rather rare in the neighbourhood of Minbu ; I have found numerous fragments of bones, belonging probably to the same species of *Trionyx* which is so common near Yenangyoung, imbedded in the conglomeratic beds along the bank of the river, but they were too ill-preserved to be specifically determinated.

No attempt has been made to sub-divide this series, which consists of certainly not less than 5,000 feet of sandstones, alternating with conglomeratic or occasionally argillaceous beds. The monotonous character of these beds, together with the scarcity of fossils, render sub-division extremely difficult. In addition to this the country is covered with a low but dense jungle which effectually hides all structural details.

B.—The Miocene or Pegu series.

While the pliocene almost completely composes the country around Minbu the miocene crops out only within a small area along the axis of the anticlinal arch. It is questionable whether the entire sequence of the Burma miocene, namely, both the Yenangyoung and the Prome stages are superficially seen. It is certain that the Yenangyoung stage exists, but it seems doubtful whether the Prome beds come to the surface, whereas they are unquestionably developed in greater depth.

Lithological and palæontological characters.

The strata of this series consist chiefly of olive coloured or bluish clays and olive coloured rather soft sandstones, the latter frequently contain layers of elongated sandstone concretions.

The Yenangyoung beds have yielded a good collection of fossils which I have described in a separate memoir.[1] As the geological position of this fauna has been discussed in detail elsewhere[2] it would be superfluous to repeat my views, so recently expressed,

[1] *Supra*, pp. 1–45.

[2] The development and sub-division of the Tertiary system in Burma. Records of the Geol. Sur. of India, 1895, Vol. XXVIII, p. 59.

and it will be sufficient to say that the composition of the fauna is somewhat different from that of Singu and Yenangyat, and that it holds most probably an intermediate position between those two faunas.

3.—Stratigraphical features.

Any section from the river bank towards west at once demonstrates that the strata form a rather high, but unsymmetrical, anticlinal arch, the sides of which are formed by the beds of the Irawadi series, while in its centre the Pegu series is exposed.

Along the river bank the beds dip vertically, and in some places are even reversed; the vertical dip continues along a distance of approximately 1,000 feet to the west from the river bank, that is to say, the hill range running immediately along the river bank is throughout composed of the steeply inclined beds of the Yenangyoung stage and Irawadi series. Towards west the dip gradually lessens, and within a distance of about 600 feet from the western foot of the hill range the strata dip at an angle of about 15° towards east. Unfortunately the gradual change in the inclination of the beds cannot be observed because a valley filled with débris intervenes. The dip lessens gradually till finally the beds are seen to be perfectly horizontal in the low ridge closing the valley in which the mud volcanoes are situated towards north; from this point the strata dip rather quickly toward west, but the angle of about 12° to 15° is very constant and does not increase as far as I have traced them towards west.

Judging from this structure, the strata form here a true fold, on the top of which the mud volcanoes and natural oil springs are situated. I am unable to say how far south this anticlinal arch extends; towards north it seems to come to an end within a few miles of Minbu, where the alluvial plain of the Mon river butts immediately on the tertiary rocks; but I am unable to say whether the latter dip normally below the alluvial deposits, or whether a cross fault has cut off the anticlinal.

Towards south the anticlinal has been traced to about ten miles south of Minbu, beyond which I have not followed it. Along the anticlinal petroleum oozes out from the surface at several localities, but the principal place, where there are the most numerous indications, is immediately west of the European quarters of Minbu, in a valley in which are situated the famous mud volcanoes of Minbu, described in the following section.

4.—The Mud Volcanoes.

Although the Nagabwet taung of Minbu have been a source of great wonder to the natives for ages past, they are hardly mentioned in the earlier descriptions of Burma. The reason for this is that Minbu was seldom visited by travellers, being somewhat off the general route taken by the boats which ply on the Irawadi.

Dr. Oldham was the first to give an account of them, but being pressed for time he could not go into details. According to his description the cones must have been much lower in 1855 than they are now, as their height is stated to be between 12 and 15 feet. Unfortunately Dr. Oldham has not stated how many cones existed at the time of his visit; it would have been of great interest to know whether the number of those mud wells, which rise on the top of cones, has changed during the last 40 years. It is however quite evident that at the time of Dr. Oldham's visit there existed the two groups, here described as the southern and northern group, which differ as regards physical aspects. The most remarkable fact of Dr. Oldham's observations is his statement of the temperature which he gives at 87° F., this is decidedly higher than has been observed by me in any of the mud wells except one. I may mention here that Dr. Oldham visited Minbu at the end of October, that is to say, just before the beginning of the cold season.

1.—Situation of the mud volcanoes.

They are situated about 3,000 feet west of the civil station of Minbu, in a narrow valley running north and south, which joins the Sabwet-choung to the south; the northern end forms a kind of elliptical amphitheatre. Having visited Minbu at different times, in February 1888, May 1889 and March 1895, I am able to record the changes which each of these mud volcanoes have undergone during the last seven years. In describing them, I will begin with the southern one, and proceeding towards north will describe a number of wells in convenient groups.

2.—Detailed description: A. Southern group.

Under the term southern group I include all mud volcanoes which are situated west of the Sekkate Pagoda, close to the northern bank of the Sabwet-choung; they extend over an area of about 1,100 feet in length and about 250 feet in breadth.

No. 1.—This, the southernmost mud volcano, is situated on a very low cone, with gentle slopes. In 1888 and 1889 there existed simply an irregular elliptical, shallow basin filled with water, in which a few gas bubbles rose occasionally. To all appearance it seemed to be extinct. In March 1895 I found it exceedingly active. Its former ground plan of an irregular basin of a diameter of about 4' × 5' was still retained, but this was filled with liquid mud, the surface of which remained a few inches below the rim. Small gas bubbles rose slowly and at irregular intervals; when a particular strong outburst took place, it threw the mud noisily over the rim. A strong smell of petroleum was noticed and the mud was covered with a streaky black film. Temperature of the mud 84° F.

No. 2.—This mud volcano forms a very low cone with gently inclined slopes, on the flat top of which are the chief vents, while on the sides there are numerous parasitic cones. In February 1888 I observed eight chief vents, which were all very active, ejecting a watery mud. The gas bubbles rose slowlier in some of them than in others; the temperatures observed were—

a	vent	=	80° F.
b	,,	=	80° F.
c	,,	=	75° F.
d	,,	=	82° F.
e	,,	=	77° F.
f	,,	=	76° F.
g	,,	=	82° F.
h	,,	=	75° F.

In 1889 the general shape had not altered; there were still eight vents visible, of which, however, one on the top of a low parasitic cone, had ceased to be active, while a second one ejected gas only, which came out with hissing noise without being accompanied by mud. The northern vent was the most active; it formed a crater-like basin filled with muddy water, which seemed to be in a state of boiling caused by the incessant rise of gas bubbles. Five feet to the west of this was another, and 15 feet south of the first a third vent. These three vents were all situated inside a low crater filled with mud in a more or less liquid state. Of the smaller ones, a low cone, which was very active in the previous year, had ceased to be active, the others were small holes filled with watery mud in which gas bubbles rose.

In March 1895 there were, besides a number of smaller, seven chief vents, one of which, the low cone already mentioned, was not active. The others were all more or less active, and produced in one case a considerable stream of mud. Beginning in the south, vent (*a*) is represented merely by an opening out of which flows a stream of very liquid mud. The opening itself is marked by the incessant rise of gas bubbles; the temperature of the mud was 84° F.

Next to this, about 10 feet west, were a series of small holes, filled with very liquid mud, one of which was very active, incessantly throwing up gas bubbles; the temperature of the mud was 79° F., whilst in another case it was 78° F.

(*c*) About 30 feet north of (*a*) there were a series of small vents arranged in a line running in easterly direction towards (*g*), the extinguished cone. None of these vents were very active. A small stream of very viscous mud was flowing out from the largest vent (*c*); gas bubbles were rare.

(*d*) About 7 feet north of (*c*) there was a hole which was exceedingly active. A large stream of watery mud flowed out of it, and the position of the hole was marked by the permanent rise of large gas bubbles, which sometimes threw the mud some distance up, but without forming a crater or cone. The temperature was 85° F.

(*e*) About 24 feet east of (*d*) was a crater-like circular basin, filled to the rim with very liquid mud, which slowly flowed over; gas bubbles were rising continuously. The temperature of the mud was 78° F.

(*f*) Five feet east of (*e*) was a small hole filled with very viscous mud at 80° F., in which small gas bubbles rose slowly.

(*g*) South of it, and in the continuation of the line of vents (*c*), was a small cone about 3 feet high, built up of flakes of mud which spurted out from the vent. It was entirely extinct and at the time surrounded by more recent streams of mud. The smell of petroleum was strong everywhere, and the mud was covered with a black film.

From the above description it is clear that mud volcano No. 2 has retained its low conical shape during the last seven years. It also seems as if the number of main vents remained the same, but I am certain that their position has shifted, although I am unable to say to what extent and in what direction. The nature of the mud thrown out has not changed since 1888, and although there are traces of a cone, the force was apparently insufficient to eject it to any distance. In 1888 the temperature of the mud varied from 75° F. to 82° F.; in 1895 the lowest temperature recorded was 78°, while the highest was 84° F. All the vents seemed to work independently, although it must be noticed that when No. 1 had its paroxysms, No. 2 simultaneously spurted out large gas bubbles.

No. 3.—With this a group of mud volcanoes begins, which have all thrown up cones; No. 3 is a double cone, that is to say, on a common basis of about 100 feet in length, rise two cones to about 30 feet above the ground, separated from each other by a saddle of about 25 feet in width. In 1888 No. 3 (*a*) was very active, there were three vents, out of which flowed a small stream of viscous mud; the temperatures recorded were 69°, 75°, 77° F.

In 1889 there existed only one vent at the top of the cone, having a diameter of about half a foot. The mud did not rise to the rim, but remained about 5 feet below it, in a sort of narrow funnel; occasionally gas bubbles rose with some force, by which flakes of very viscous mud were thrown over the rim. In 1895 the general shape of the cone had not changed in any way, but on its top there was a crater of about five feet in diameter filled with a very viscous mud which slowly flowed off through a break on the eastern rim of the crater. The temperature of the mud was 82° F.

3(*b*) To the west of No. 3 (*a*), rises a blunt cone No. 3 (*b*), which has not been active since 1888; its sides are much denuded by rain water, which has eroded deep furrows in it. On its west side, close to the base is a small vent, hardly a few inches in diameter, which is filled with liquid mud.

3(*c*) On the southern side of 3 (*a*), close to the base, is a parasitic cone of about 6 feet in height with very steep slopes. In 1888 and 1889 there was a small crater at the top filled with muddy water, which was slowly flowing off. In 1895 it had entirely ceased to act.

From the above description it will be seen that the general shape of No. 3 cone had not altered. It is, however, quite certain that the vent of No. 3 (*a*) has undergone several changes, that it was comparatively active in 1888; in 1889 the activity had decreased, while in 1895 it begun with renewed vigour. Vent 3 (*b*) showed no signs of a change, while No. 3 (*c*) had become entirely extinct. The temperature also exhibits some changes; in 1888 it was between 69° and 77° while in 1895 it was at the same vent 82° F.

No. 4.—A high cone rising about 40 feet, north of No. 3 (*a*). Like the former, it consists of a gently inclined base on which rises rather suddenly a cone with very steep sides. In 1888 it hardly exhibited any signs of activity; there was a small vent on the top, out of which flowed a narrow stream of mud with a temperature of 75° F. In 1889 it had resumed its activity; on the top was a crater of about a foot and a half in diameter filled with a very viscous mud, which rose to the rim of the crater, gas bubbles were frequent and large, and after a very heavy outburst the mud ran over the rim. In 1895 the cone had again relapsed into inactivity, but at its northern base where it seemed to have been traversed by some deep fissures very viscous mud spurted out periodically from a small hole, and with such force, that it was thrown up in the air. A stream of mud apparently issued from this vent, whose exact position could not be traced owing to its being hidden below mud. Another parasitic cone at the northern end was dry.

The general shape of this cone has not changed, but its activity exhibited great variations. From being nearly extinct in 1888 it rose to a state of comparative activity in 1895, but since that time it has quieted down considerably.

No. 5.—This is the most remarkable of all the mud volcanoes near Minbu; it is the largest and highest amongst them and is at the same time the most active. It has undergone various changes since 1888; measured from the northern foot of No. 4 it is about 300 feet to the north of that cone, and rises in a rather steep cone of about 40 to 45 feet in height on a very gently inclined and broad basis.

In 1888 it formed a single cone with a crater of about 6 feet in diameter, which was filled with a very viscous mud in which rose enormous bubbles of an inflammable gas with a strong petroliferous odour. The rise of the gas bubbles produced a gurgling noise, then the surface of the mud slowly rose in a huge bubble which fell back on bursting, producing a kind of concentrically rippled surface on the mud which fills the crater. The temperature was 76° F.

To the south-east were two smaller vents with watery mud at the same temperature.

In 1889 the same vent was as active as before. I noticed, however, a remarkable occurrence; within 24 hours the level of the mud which filled the crater rose by about 6 inches. The first day when I visited it, the surface of the mud was about 6 inches below the rim of the crater; on the second day it had risen and filled the crater to the rim; the smaller vents, on the south-eastern side were very active.

In 1895 the smaller vents had combined and formed a second main crater towards south-east, separated from the older crater by a low saddle in which there was a third vent (See plate III). The new or southern vent, 5*a*, formed a circular crater of about 5 feet in diameter, in which the mud did not quite rise up to the rim, but remained about 5 inches below it. It flowed off through a small break at the western side. Gas bubbles were large and frequent. The temperature was 78° F.

The northern or older vent 5*b* formed a crater of about three and a-half feet in diameter, filled to the rim with very viscous mud, in which small gas bubbles rose. At long intervals a stronger eruption took place, when the mud overflowed; the temperature was 78° F.

Between the two was a third vent, 5*c*, of about a foot and a-half in diameter filled with very liquid mud, which did not reach up to the rim; gas bubbles rose, but not frequently; the temperature was 75° F.

From the above description we see that this mud volcano underwent great changes with regard to its shape; from being a single vented cone in 1888 it changed to a double cone in 1895.

No. 6.—Rather less than 200 feet north of the former the last of the cone rises to a height of about 35 feet. In its general shape it resembles the No. 3*a*; in 1888 it was only feebly active. There were two vents on the top, from which a small stream of mud flowed with a temperature of 75° F. The same two vents were seen in 1889; the northern being the smaller of the two. There was no stream of mud flowing, but occasional flakes of mud were thrown out of the vents. In 1895 there was only one vent at the top, of about 6 inches in diameter, filled with a very viscous mud which did not reach the rim. Occasionally gas bubbles rose, spurting out small flakes of mud. The temperature of the mud was 75° F. A small vent at the northern foot contained very liquid mud of 78° F.

The mud volcano has not suffered any changes in its general shape since 1888, although it is quite certain that the vents have shifted.

No. 7.—This is an irregular basin filled with muddy water up to about 2 feet below the rim, west of No. 4, but not strictly speaking, belonging to the group Nos. 3 to 5, its physical appearance being more related to Nos. 1 and 2. Gas bubbles are frequent and the water is covered with a thin film of petroleum. The temperature is 76° F.

It is remarkable that while mud volcano No. 5 underwent such considerable changes since 1888, this one has not changed in the slightest degree since that year, notwithstanding there being a continuous rise of gas bubbles. The crater-like basin, partly filled with water in which bubbles rise, was the same in 1888 as in 1895.

Besides these active mud volcanoes there are the remains of at least two extinct ones, which must once have possessed cones of considerable height, but are now almost entirely denuded by rain, leaving only their base still visible. One of them (A) is close to the southern base of No. 3, shown on plate I; the second one (B) is east of No. 2; it is not represented on any of the plates.

B.—Middle group.

About 700 feet north of the group mentioned above there are a few smaller mud holes, one of which is particularly active. It forms a crater like basin of about 7 feet in diameter, which is filled with muddy water in which gas bubbles rise incessantly; the mud has a temperature of 82° F. and is covered with a thick continuous brown film of petroleum. Besides this there are a few small cones, around which the ground is saturated with petroleum. None of them were active, and only one emitted gas with a hissing noise. No changes have been recorded since 1888.

C.—Northern group.

About 1,300 feet north of No. 6 there is another group of vents which, although very active, scarcely deserve the name of mud volcanoes. These wells are all more or less irregular basins which are filled with a watery mud, in which small but numerous gas bubbles rise incessantly. The surface of the water is always covered with a thick film of petroleum.

The largest of these holes forms an irregular basin of about

50 × 20 feet, filled with a watery mud of about 82° F. Inside this basin there are numerous independent vents, which emit gas continuously, some of them with a hissing noise; the surface of the mud was covered with a thick film of petroleum. The principal basin is surrounded by numerous vents, some of which emit gas only, while others eject a very viscous mud, mixed with petroleum. The temperature varied from 79° F. to 82° F.

Several vents of this same kind are found a short distance north of this one; in all cases a more or less circular basin is filled with a watery mud in which numerous gas bubbles rise. The northernmost of these holes, just at the foot of the hill, is remarkable for its comparatively high temperature, which was repeatedly measured and found to be 97°. I first attributed it to the heating influence of the sun, but after having found the same temperature early in the morning, before sunrise, it must be considered as the actual temperature of this mud well.

3.—General features.

So far it appears that the mud volcanoes have little in common in general shape, but we shall eventually see that the basin shaped mud wells and the conical mud volcanoes are only modifications of one and the same phenomenon.

The features in common are: they all produce a greyish blue mud, of varying consistency, more or less saturated with petroleum, and emitting an inflammable gas in smaller or greater quantities. It appears unquestionable that the mud volcanoes of Minbu are more or less intimately connected with subterraneous petroliferous strata, and their position on the west of the anticlinal arch is therefore by no means accidental. The mud brought up by the mud volcanoes resembles in fact so much the débris baled out of the drilled wells at Kodoung, that samples of both cannot be distinguished.

The source from which the mud and gas rises cannot possibly be very deep below the surface; this is indicated by the low temperature of the ejected mud. Except one well in the northern group, which has a temperature of 97° F., the temperature is never higher than 85°, but even this and the next lower temperature, 84°, are not common; the bulk of the wells possess a temperature between 75° F. and 82° F., that is to say the temperature is much lower than that recorded in any of the pit wells of the Yenangyoung oil field. It is therefore beyond doubt that the source of the mud volcanoes must be close to the surface.

The fact must also not be overlooked, that often wells which are close to each other differ in temperature, though not greatly. Much more important appears to me the probability that, owing to the superficial position of the beds from which the mud and gas is derived, the temperature changes with the season. This hypothesis could easily be confirmed by a series of observations extending over a few years.

If the change of the temperature with the season cannot be absolutely proved, for the present it is quite certain that the activity of the mud wells changes with the season, or more accurately with the level of the river. When the river is high, the mud volcanoes are very active, when it is low, they subside into a comparative state of rest.

I first visited the mud volcanoes in February 1888 when they were at a comparative state of rest, but in June 1888 when I revisited Minbu they were all very active. The same applies to my visit in May 1889, when they were all more or less active, while in March 1895, they were generally speaking less active. It seems to me no mere accident that a greater activity should coincide with the high level of the river during the rains or a state of comparative rest with that of a low level during the dry season. Having already mentioned that the source of the ejected mud cannot possibly be very deep, it is probable that the change in the level of the ground water, which must happen with the rise and fall of the river, influences the activity of the mud volcanoes.

With regard to the general shape of the mud volcanoes we may distinguish two types, *viz.* :—

(*a*) Basins.
(*b*) Cones.

In their extremes the two types are well distinguished, and no greater contrast could be imagined than that which exists between mud volcano No. 5 (see plates III and IV) and one of the wells in the northern group, but No. 1 of the southern group proves distinctly that these are simply different effects of one and the same cause, an explanation of which will be given presently.

(*a*) *Basins.*—The basins are more or less circular or elliptical holes formed in the ground. When dry it may be seen that their walls are steep and the bottom rounded. When in activity the basins are filled with muddy water, which generally forms a sediment ; from the bottom rise incessantly numerous small gas bubbles which give the liquid the appearence of boiling. Some of the vents seem rather constant, as indicated by the rise of the gas bubbles; others are only temporary; the gas rises for some time at a certain spot, the vent becomes clogged and fresh gas bubbles rise at another place. Petroleum is brought up with the gas and forms a more or less continuous film on the surface of the water.

Although most of the basins are permanently in a state of activity, they never produce mud streams of any extent. This applies particularly to the northern group. The general shape of the great well No. 1 has not altered since 1888, nor has that of any of the other wells, for instance, No. 7 of the southern group.

(*b*) *Cones.*—The cones are built up of mud streams, generally with very steep sides, as may be gathered from any of the plates, illustrating them. We may assume, that before the steep upper cone was finished, the vent was situated on a low flat cone such as is represented mud volcano No. 1. The conditions for the raising of a cone seem to be the presence of a great mass of viscous mud combined with certain amount of gas pressure. In this case the mud is ejected in flakes, which are thrown up high in the air and fall back with a splashing noise around the vent. If the action goes on for some time a cone is raised, whose surface shows the same flaky structure as noticed in the fumaroles of a lava stream, and on the top of which is a crater-like basin filled with mud, through which the gas rises. Secondary vents frequently appear on the sides of the cone, and they may in time become more important, eventually assuming the position of a chief vent. This is beautifully illustrated by mud volcano No. 5. It is obvious that with the rise of the cone, the mouth of the vent, which ejects the mud, rises above the surface, and a certain pressure is required to overcome the weight of the mud in the vent. It does not seem, however, that the gas pressure is anything very large, because a height of 40 feet from the surface to the summit of the cone seems to be sufficient to counteract the explosive force of the gas, which then only slowly rises in bubbles through the mud. The cones generally produce streams of mud of smaller or greater viscosity. When the mud in the crater has risen to the rim, an overflow takes place, and the mud runs down the sides of the cone, quickly at the upper part, where the sides are steep, and more slowly on the base, where the gradient of the slope is very small.

The first part of a mud stream generally dries up very quickly, but still retaining some moisture, it forms a pavement on which the subsequently ejected masses flow, without their movement being too much slackened by the loss of moisture at their lower side. When the activity of the mud volcano continues, the spasmodic gas eruptions produce many spasmodic overflows of the mud in the crater. The ejected mud, flowing for some time in the same direction down the slope, forms, in consequence of the loss of moisture along its sides, a narrow channel with raised sides (see plates V, VI, and VII) inside which the later ejected mud runs down rapidly, till its movement is arrested along the lesser slope near the base of the cone. Now the stream begins to spread out; the walls of the channel gradually diverge (plate VI), driven aside by the pressure of the fresh masses, but still they continue almost to the end of the stream. Inside the walls the mud flows with lesser and lesser speed, partly on account of the small gradient, partly on account of the loss of moisture, and as new masses press on from above, the partly solidified mud cannot move forward, it is therefore raised and shaped into folds which produce a curiously wrinkled surface (plate VI). The wrinkles run transversally across the stream, and more advanced in the centre than at the sides.

The end of the mud stream, where the loss of moisture is rather rapid, shows a curious rugged structure, resembling very much that of the front of a lava stream. The central part of the mud stream, which looses its moisture less rapidly and dries more slowly, is therefore in a dried state intersected by numerous longitudinal cracks (see plate VI).

The plates V to VII illustrate these streams; on plate V is figured the top part of mud volcano No. 5 as it appeared in May 1889; the narrow channel with its raised edges is extremely well seen. Plate VI illustrates the lower end of the same stream as seen from above, the diverging of the side walls, the sigmoidal wrinkles on the centre of the stream, as well as the longitudinal cracks in old dried up streams are well exhibited. Plate VII exhibits the lower part of a mud stream running from the right to the left.

Origin of the mud volcanoes.—The question why these mud volcanoes should have formed near Minbu only, and not at other localities, such as Yenangyoung or Yenangyat, is a difficult one to answer if we consider that at the two last named localities the same conditions prevail as at Minbu. At Yenangyoung, but particularly at Yenangyat, there is a high pressure of gas sufficient to produce flowing wells. At both localities the drill has proved that there exist thick layers of clay, and that there is an ample supply of water, in fact everything required for the existence of mud volcanoes, yet there is not the slightest trace of them at either locality. From this it seems quite clear that some other conditions must prevail which cause mud volcanoes, and that clay, gas and water are not by themselves sufficient to produce them.

The examination of the country around suggested, however, an idea which may afford some sort of an explanation. I have pointed out that the mud volcanoes are situated in an elongated horseshoe shaped valley, filled with recent argillaceous beds. It is probable that this horseshoe shaped valley has been caused through subsidence of part of the miocene strata below; at least the appearance of the northern, eastern and western side seem to support such a view, though it is possible that it is only a valley of erosion. The question of the nature of this valley is, however, only of secondary importance; the fact remains that here is a basin of tertiary strata covered by recent alluvial beds. I believe the petroleum and gas rose along fissures in the tertiary beds below, and were arrested by the impermeable layer of alluvial clay which covers the tertiary beds as stated, so that when the pressure of gas and petroleum collected immediately under this covering layer, had acquired sufficient force to break through the superimposed alluvium, it formed a mud volcano. In the other cases the pressure may have been gradually relieved through existing fissures. As it is more than probable that the alluvial clay rests on strata charged fully by ground water, the above hypothesis would explain—

(*a*) The low temperature of the mud ejected by the mud volcanoes.

(*b*) Their periodical change of the activity.

The following diagram woodcut, fig. 1, will illustrate this view, but I must mention that I do not insist on this explanation being applicable to mud volcanoes elsewhere.

Unfortunately I have not seen yet the large mud volcanoes of Ramri and Cheduba island on the Arrakan coast, and I cannot therefore say in what relation they stand to the mud holes of Minbu.

Mr. Mallet's otherwise so exhaustive paper[1] does not say whether the mud volcanoes of these islands are directly built up on tertiary beds or on alluvial strata.

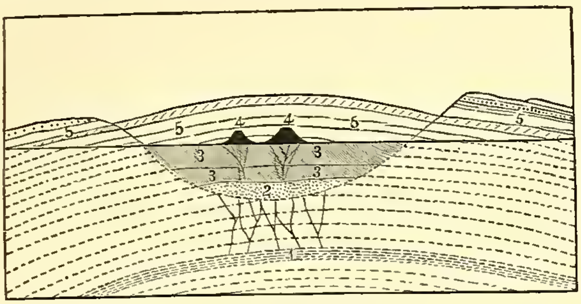


Fig. 1.—Diagrammatic section through the Minbu mud volcanoes.

In conclusion I may say, that no fiery eruptions have been observed at Minbu; the gas is inflammable, but there are no instances on record of its spontaneous ignition. If ignited, the gas bubbles will explode with a faint flame, but every new bubble will have to be ignited again. I have been told that some of the northern wells had been set on fire, where the petroleum occurs in a thick film, but this cannot have burnt very long as no traces of it were visible.

Chapter IV.—THE PETROLEUM FIELD OF YENANGYOUNG.

1.—Geographical position, area, and physical geography.

According to the latest map of the Survey of India, the village of Yenangyoung[2] is situated at Lat. 20° 29′ N. and Long. 94° 56′ E. on the left bank of the Irawadi, in the Magwe District of the Southern Division of Burma. The petroleum field is not exactly close by to the village, but lies some distance inland towards east. This distance has been variously estimated by different visitors as between three

[1] The mud volcanoes of Ramri and Cheduba. Records, Geol. Surv. of India, XI, 188—207 (1878).

[2] The name of this village has been variously spelled as Ranangoong, Rainanghong, Yanangheoum, Yunanyaung, Yenan Gyong, Rainoung or even Hong Ragoon, all, however, referring to one and the same locality, Yenangyoung.

and five miles from the river. The latest survey has, however, proved that even following the winding cartroad, the distance from the river to the central point of the oil tract is exactly two miles and a quarter.

Formerly oil was produced at two separate localities, the villages of Beme and Twingon, separated by a tract measuring in a straight line about three quarters of a mile (more correctly 60 to 62 chains), called Kodoung. Since 1887 boring operations have been carried out at Kodoung, and this part forms now the chief oil centre of the field. It may be useful to deal shortly with the different parts composing the Yenangyoung oil field, although they are now but of historical interest.

(*a*) *The Beme tract.*

When the stream, which falls into the Irawadi directly south of the village of Yenangyoung, generally styled Yenangyoung-choung, is followed up, it divides at a distance of two and a quarter miles from the river into two branches. The southern branch runs roughly in an east and west direction, and is called Taungle-yo, the northern branch Kunnhitse-yo. Inside the triangle formed by these two streams is the Beme oil field; at the point of junction lies the small village of Beme.

The pit wells are chiefly situated in two narrow ravines, and on the slopes of a bifurcated spur, projecting from the plateau in a westerly direction. The total area occupied by the wells covers 31·2 acres, that is to say, an insignificantly small area. Under the recent settlement the area reserved for the native well diggers has been extended to 83·4 acres, which, including the area occupied by Government wells, brings up the total area of the so called Beme native reserve to 90·2 acres. In the light of our present knowledge regarding the geological structure of the oil-bearing beds it may, however, be fairly doubted whether the whole of this area will yield oil. In fact my opinion is that if the area likely to yield petroleum is estimated at 74 acres, it is rather above than below the mark.

It seems that the systematic extraction of petroleum was first started at the Beme oil tract, but it is impossible to say how far back this dates. It is unquestionable that the oil field was in full working order at the end of the last century, but I doubt whether the production of oil dates back to prehistoric times as some authors have supposed it to do. Surely the exploitation of an oil field during say only 2,000 years ought to have left some traces behind, but there is nothing to point to it being worked more than 200 years. At present the Beme tract is exploited by pits and a few drilled wells; seven in all have been sunk in the Government holdings, but it cannot be said that they have been a success from a commercial point of view. In fact every indication points to the probability that the petroliferous sands within the Beme tract are fairly exhausted.

(*b*) *The Kodoung tract.*

Immediately to the north of Beme follows the Kodoung tract, which chiefly occupies the land on the plateau between the Kunnhitse-yo (northern branch of the Yenangyoung choung) on the south and the Aungban-yo on the north. The length of this tract is about 52 chains, and its breadth is at the outside 40 chains; the area known to produce oil can, for the present, be estimated at the outside at 108 acres; its western limit has been clearly defined by the results of the deep borings, the northern and southern boundary are fixed, it is therefore only the eastern boundary about which there might be some uncertainty. However, as far as my experience goes, the easternmost well cannot be far off from the eastern limit of the petroliferous tract, and the above estimate of 108 acres allows a very fair margin in my opinion.

The Kodoung area is at present exploited by 58 drilled wells which produce on the average about 12,891 barrels a month. For further details I refer the reader to Chapter IX.

(*c*). *The Twingon tract.*

Immediately to the north of Kodoung and separated from it by the narrow but steep Aungban-yo is the oil tract of Twingon. The area covered by the pit wells forms a somewhat irregular square, limited to the north by the Natsin-yo, and south by the Aungban-yo. Eastern and western limits are less well defined, but it may be said that the wells do not extend beyond the eastern village of Twingon, while west they extend right up to the boundary line of the "Reserve." The area thus occupied by the pit wells may be estimated at about 200 acres.

The total area reserved for the native well diggers covers 310·02 acres, but as in the case of Beme it may be fairly doubted whether petroleum is found all over this area. The Twingon tract is at present exploited by 519 productive wells, which produce by far the larger share of the yield of the pit wells, the average being 7,900 barrels a month. It seems at present at the zenith of its production, in fact, it looks as if it had already passed it.

To sum up, the area of the Yenangyoung oil field is made up by—

	Acres.
1. The Beme tract	311·2
2. The Kodoung tract . . .	108
3. The Twingon	200
TOTAL .	349·2

say, 350 acres, or rather more than half a square mile.

The land north of the Twingon tract and adjoining it has not yet been thoroughly tested; there are two drilled wells in Block 2 N., one of which has yielded oil, the other not. Both are, however, closely situated to the boundary of the Reserve. It would, therefore, be hazardous to say anything definite: but I think I am not far from the mark if I estimate the length of the whole of the Yenangyoung oil tract not to exceed 2 miles, while its average breadth amounts barely to more than ¼ mile.

(*d*) *Physical Geography.*

The country in the neighbourhood of Yenangyoung forms part of the low plateau like land which extends between the high elevations of the Shan hills and the Arrakan Yoma. Near Yenangyoung the plateau represents the aspect of a perfect plain, slowly rising inland as far as the eye can see. But on closer examination one is surprised to find this plain intersected by innumerable ravines and gullies, producing thus the most rugged ground which it is possible to imagine.

At its highest point, Minlindoung, the plateau rises to 534 feet above sea level, but its average height is not much above 480, that is to say, about 250 feet above the high water level of the river. Excepting the Pin-choung, which does not exactly come within the area here dealt with, there is no stream containing water all the year round. Although deeply cut into the ground the ravines are dry for nearly the whole of the year, and only during the rainy season do they contain water, but owing to their rapid fall the water is quickly discharged, and the ravines remain dry till another downpour causes a fresh flood. It is hardly possible to imagine the suddenness with which these torrents appear after a heavy shower of rain, and how quickly they subside again. I once witnessed the Yenangyoung stream, which was nearly dry, rise within half an hour about five feet, and subside to its former level within less than an hour, leaving its bed strewn with masses of debris.

It need hardly be mentioned that a country of this kind offers the most serious obstacles to communication. The roads have to wind about along the spurs and on the plateau, in order to avoid the continuous descents and ascents when crossing ravines, so that a distance of a mile in a straight line is generally doubled along the road.

From a geological point of view, these ravines are very favourable, as, owing to the dryness of the country, vegetation is scarce, and thus the strata are scarcely hidden by the vegetable growth, which in Burma generally conceals all stratigraphical features. It is chiefly owing to these favourable physical conditions that it was possible to study the geological structure of the Yenangyoung oil field; otherwise it would have been quite impossible to recognize any of the subdivisions in this great thickness of arenaceous and argillaceous beds, which are all exactly alike whether found at the bottom or at the top of the series. Even now the subdivisions of the Yenangyoung tertiaries, as described in the following pages, must only be considered as a first attempt; it remains to be seen how far it will hold good for the larger part of the Burman tertiaries.

2.—Geological Features.

The strata developed in the neighbourhood of Yenangyoung may be divided as follows:—

A. Diluvium.
B. The tertiary system.

A.—Diluvium.

It might perhaps be questioned whether this term ought to be applied to the beds which I am here briefly describing; it is not impossible that perhaps the term older alluvium would be better, as we do not possess absolute evidence by which the diluvial formations in Burma can be correlated to the same formations in Europe.

I consider as diluvial all those strata which rest unconformably on the tilted beds of the pliocene in such a manner that they can be clearly recognized as having been formed before the present system of drainage was established.

Within the limits of the above definition the diluvial strata can be easily recognized everywhere in Burma, as they are generally found high above the level of the present rivers, and are always cut into by the present drainage. Near Yenangyoung two facies of such beds may be observed, namely:—

(1) Lower silt.
(2) Plateau gravel.

(1) *The lower silt.*—The lower silt may be noticed just south of the Pin-choung, but becomes more conspicuous near Kyaukse, where it is a fine silt, horizontally bedded, and apparently deposited in the synclinals and hollows of the pliocene beds, which it most closely resembles lithologically, and for which it might easily be taken, if the bedding is not clearly seen. At Kyaukse, I observed on the river bank, that typical pliocene beds, dipping towards west, were unconformably overlaid by a series of horizontal beds of fine silt;

the latter, notwithstanding their great lithological similarity, must of course be of much later date than the pliocene strata.

I had no time to spare to examine the lower silt in detail, but it does not seem to contain fossils.

(2) *The plateau gravel.*—Almost everywhere in the central part of Burma, the pliocene beds are covered by a bed of coarse gravel of varying thickness. The gravel consists chiefly of well rolled, large pebbles of white cellular quartz, rolled fragments of silicified wood, and sometimes rolled fragments of fossil bones. Judging from the latter it seems evident, that the plateau gravel has been largely derived from the eroded pliocene beds, but to what parts and in what direction we have to look for the origin of the quartz pebbles remains an unsolved problem for the present. There are conglomeratic beds in the lower part of the Prome beds in the Chindwin country, but it is doubtful whether the large pebbles in the neighbourhood of Yenangyoung could be derived from them.

The most astonishing fact is the size of these quartz pebbles, which are as large as a man's fist, and sometimes still larger. Pebbles of this size cannot have been transported to their present locality from the Shan hills, or the country north of Bhamo where metamorphic rocks occur. In this case the drainage of the country must have undergone considerable changes since these pebbles were deposited; at present the Irawadi forms only sand banks of the finest sand or silt not only in this part of the country, but also higher up its course. How, therefore, these quartz pebbles could have been transported to their present resting place, when their size proves that they could not have been transported a very long distance, and within a long distance there are no older strata containing such quartz pebbles, from which they could have been possibly derived, remains at present a problem which I am unable to solve. I may mention that the presence of these pebbles could not be explained as of glacial origin; so far as known to me, there are not the slightest traces of glacial conditions either in the past or present to be found in Burma.

The plateau conglomerate often forms a hard bank, its parts being firmly bound together by a ferruginous cement; this appearance, together with the frequent occurrence of fossil wood, have frequently induced other observers to include it among the Tertiary system, particularly as ferruginous conglomerates, not nearly so coarse however, are of no infrequent occurrence within the pliocene division. Its unconformable position on pliocene beds will, however, readily distinguish the plateau conglomerate.

So far as known to me it chiefly occurs within a certain height above the present level of the river, apparently not exceeding 400 feet above sea-level, and generally between 300 and 400 feet. It usually occurs in isolated patches capping the pliocene beds, but more extensive deposits are by no means infrequently found. I am not in a position to state exactly what are the relations between the lower silt and the plateau gravel; it seems quite evident that the lower silt is overlaid by the plateau gravel, but I also noticed between Kyaukse and Yenangyoung a conglomeratic bed which could not possibly be distinguished from the plateau gravel, interstratified with the lower silt.

The above outlines of the diluvial strata of Burma do not aim at being exhaustive, and I only mention the subject, since the plateau gravel has been so frequently wrongly identified with the tertiary system.

B.—The Tertiary system.

In the neighbourhood of Yenangyoung only the younger tertiaries appear on the surface, but this does not exclude the probability that older tertiaries occur below.

1.—The Pliocene or Irawadi series.

(*a*) *Lithological characters.*—The principal rock of the Irawadi series is a very soft, friable sandstone, perhaps better termed sand rock. It is generally of light yellowish colour, sometimes almost white. In the lower parts strings of nodular or kidney shaped concretions of hard silicious sandstone are frequently met with; in the upper part calcareous concretions of various irregular shapes resembling fossil roots or bones, are very common.

Of more subordinate importance are beds of ferruginous conglomerate, generally forming thin and irregular layers, which resemble shingle deposits. The thickest of these beds is found at the base of the division, where it forms a very constant horizon, which I shall have occasion to describe further on.

Still more subordinate are argillaceous beds; now and then they form layers of some thickness, but generally they occur in thin beds; their colour is a greenish brown of various shades.

(*b*) *Palæontological characters.*—Near Yenangyoung the Irawadi series contains numerous specimens of bones and teeth of vertebrates. The specimens are particularly common along the river bank between Yenangyoung and Nyounghla, but fragments may be picked up almost everywhere in the more conglomeratic beds.

As I have discussed the relations of this fauna in a previous paper,[1] it is superfluous to go over the same ground again. It will suffice to say that the species determined, excepting those which are indigenous to Burma, are all identical with Siwalik species.

With regard to the recurrence of species I may mention that fragments of *Crocodilis* sp. (cf. *biporcatus*) and *Gavialis* (cf. *gangeticus*) preponderate. In fact there is hardly a conglomeratic bed in which at least a few fragments of these two species may not be found. Next come Chelonian bones, in particular *Trionyx* sp. Then follow the other animals, among which *Hippopotamus irravadicus*, *Acerotherium perimense*, *Mastodon cliftii* are more frequent than the other forms, which are generally very rare.

In conclusion I may say that the specimens are very irregularly distributed; the river bank between Yenangyoung and Nyounghla, along which in former years such rich collections have been made, barely yielded a few fragments in 1895.

[1] The Development and Subdivision of the Tertiary system in Burma. Records of the Geol. Surv. of India, 1895, XXVIII, pp. 59–86.

Besides the vertebrate fauna, silicified wood is extremely common in the Irawadi series. Huge logs and smaller fragments may be found almost anywhere throughout the beds. As I have expressed my views with regard to the origin of the fossil wood in the paper quoted, it is unnecessary to repeat them here.

Excepting the two species *Cyrena* (*Batissa*) *crawfurdi* and *Cyrena* (*Batissa*) *petrolei* which occur at the very base of the Irawadi series, and which also descend lower down, the beds forming the latter have so far been found to be absolutely destitute of invertebrates.

(*c*) *Local subdivision.*—In the neighbourhood of Yenangyoung, the Irawadi series attains a thickness of 4,630 feet measured from the base of the zone of *Hippotherium antelopinum* to the bank of the Irawadi. It is, however, quite certain that this does not by any means represent the total thickness of the division, which must be much larger even near Yenangyoung, but, owing to the want of more accurate maps, it was impossible to estimate the thickness with any accuracy.

It is beyond question that the subdivision of so lithologically uniform a sequence of beds, of a known thickness of not less than 4,600 feet is extremely difficult, if not altogether impossible. It seems, however, as if certain species of the vertebrate fauna were limited to certain horizons. Whether I am right in this supposition remains to be seen, when the Irawadi series has been studied in greater detail in other parts of Burma; but I am absolutely sure that certain species are restricted in the neighbourhood of Yenangyoung to the lower parts of the division, while others have so far been only found in the upper parts.

In descending order I distinguished three stages—

1. Sandstone, apparently containing no vertebrate remains, but plenty of fossil wood.
2. Zone of *Mastodon latidens* and *Hippopotamus irravadicus*.
3. Zone of *Hippotherium antelopinum* and *Acerotherium perimense*.

The three horizons are of very unequal value as regards thickness, inasmuch as the lower one is of not more than 20 to 25 feet in thickness, while the two upper ones include the remainder of the Irawadi series. It is quite possible that the latter is capable of a further subdivision, but owing to the inconstancy of the fossiliferous beds, and the uniform lithological character, I have not been able to distinguish more than two zones. In fact the subdivision of the beds above the zone of *Hippotherium antelopinum* into two parts is somewhat artificial, as no definite boundary between the two can be given, owing to the sameness of the lithological character of the strata. Negative evidence, the absence or scarcity of fossil remains, is in fact the only distinguishing feature.

The zone of *Mastodon latidens* and *Hippopotamus irravadicus* is formed by soft yellow sand rocks with subordinate conglomerate beds, and is characterized palæontologically by the two above-named species, which almost certainly do not occur in the lower zone.

The zone of *Hippotherium antelopinum* and *Acerotherium perimense* forms a most conspicuous horizon of the upper tertiaries near Yenangyoung. In the form of a dull red band it is visible at long distances, running continuously over hills and ravines, and encircling the Yenangyoung oil field. In fact the presence of this bed has helped in a great measure to interpret the structural relations of the Yenangyoung oil field. Lithologically this horizon is represented by a ferruginous conglomerate, which varies somewhat lithologically; at some places it is a rather incoherent agglomerate of irregularly shaped concretions of a ferruginous clay, at others it contains numerous quartz pebbles cemented by a hard conglomeratic sandstone, at others again it is an earthy iron ore, of a bright red colour.

In thickness it varies also, being of not more than 10 feet thickness at some, while at other places it swells out to about 25 or 30 feet. Palæontologically this bed is characterised by the frequent occurrence of *Hippotherium antelopinum* and *Acerotherium perimense*, neither of which rise into higher horizons. Besides these *Crocodilis* sp. *Gavialis* sp., *Trionyx* sp. are very common. Locally, particularly east of Minlindoung, it contains hundreds of the two species *Cyrena* (*Batissa*) *crawfurdi*, Noetl., and *Cyrena* (*Batissa*) *petrolei*, Noetl. It must also be mentioned that the curious chipped flints, which have been generally recognized as being of artificial origin, have been found in this bed. As I have devoted a special paper to the occurrence of these flints,[1] I need not recapitulate the facts here.

As regards the horizontal extension of this zone, it may be said that at least in the immediate neighbourhood of the Yenangyoung oil field, it forms a very constant horizon, which disappears towards north below younger beds. In a southern direction, towards Minlindoung, the individuality of this bed becomes less expressed and it seems that it dies out further to the south. If the reality of this horizon be questioned on this ground it must not be forgotten that the bed forms but one of the conglomeratic beds, of so frequent occurrence in the Irawadi division. As at the same time it seemed to be well characterized by the occurrence of certain species, it appeared to me quite admissible to distinguish it as a local horizon, but it cannot now be settled whether it forms a distinct horizon in the Irawadi division.

I particularly wish to emphasize that the above is but a first attempt to subdivide the pliocene of Burma on a palæontological basis, which will have to be confirmed by future researches, particularly in the Siwalik hills of India.

2.—The miocene or Pegu series.

(*aa*) *The upper miocene or Yenangyoung stage.*

a. Lithological characters.—It is chiefly composed of olive coloured clays, always well stratified, and sandstones of the same colour, which usually contain strings of hard concretions of considerable size. A good distinguishing feature is found by the presence of gypsum, which occurs in large crystals in the argillaceous beds. This mineral is so strictly limited to the beds below the

[1] Records, Geological Survey of India, 1894, XXVII, p. 103, and Verhandl. d. Berlin. Anthropol. Gesel., 1894, page 427.

zone of *Hippotherium antelopinum*, but above the Prome stage that it serves as a distinguishing feature. It may also be mentioned that the beds of this stage are intersected by numerous veins filled with eruptive mud (see page 80).

b. Palæontological characters.—In the neighbourhood of Yenangyoung these beds are particularly destitute of fossils. With the exception of the two species already mentioned, *viz.*, *Cyrena* (*Batissa*) *crawfurdi* and *Cyrena* (*Batissa*) *petrolei*, which have been found in the topmost bed, no other fossils have hitherto been met with.

It also deserves to be mentioned that the few fragments of fossil wood which are occasionally found are always carbonized, never silicified.

The total absence of fossil remains in this stage, excepting the two species already mentioned, is very remarkable, because further to the north, near Singh a fine marine fauna was discovered in the same horizon. The thickness of the stage is about 1,100 feet, but in the absence of any fossils it is useless to attempt further subdivision, particularly as it will be pointed out further on (see page 77) that the beds are of very limited horizontal extension. When the sections described are examined it will be apparent that a thick bed of sandstone may abruptly terminate, and be replaced by an equally thick bed of clay, thus showing the uselessness of subdividing a formation of so uniform lithological characters.

(*bb*) *The lower miocene or Prome stage.*

a. Lithological characters.—In striking contrast to the yellowish and brown tinges of the upper tertiary beds, the lower miocene is always characterised chiefly by bluish, or, in some cases, greyish colours.

As in the previously described divisions, the principal rocks are sandstones and argillaceous beds, but there are no limestones or shales.

The sandstone is very fine grained and usually very soft, but sometimes it contains more silicious cement, and in that case either thin continuous layers of a very hard, silicious grey sandstone are formed within the softer beds, or the silicious matter concentrates in the shape of globular concretions, both of which constitute great obstacles to the limited resources of the native well digger. When the sandstone is fairly soaked with oil it exhibits, when fresh, a fine grass green colour, which, however, very soon changes to a dirty brown. After being exposed for some time to the heat of the sun, the oil evaporates, and then it is seen that the sandstone is of the usual pepper and salt colour. The argillaceous beds generally consist of a very tenaceous, bluish clay, forming either continuous beds of considerable thickness, or thin layers alternating with equally thin beds of sandstone; the latter facies is known by the drillers as "shale."

Within the area of the Yenangyoung oil field only an insignificant part of the Prome stage comes to the surface, chiefly in the form of thin alternating beds of argillaceous and arenaceous character. The lithological characters can generally only be ascertained by the debris heaped round the mouths of the native wells.

b. Palæontological characters.—Fossils are apparently very rare, and I only once succeeded in finding a few in a conglomeratic bed made up of rolled lumps of clay, carbonized wood and numerous fragments of bones, about 156 feet from the surface. This bed was not more than about 4 inches in thickness and was intercalated in sand slightly charged with petroleum, and must have been of purely local character, as it does not seem to occur anywhere else. The fossils were not particularly well preserved, excepting some osseous fragments and teeth; the calcareous substance of the other fossils had been entirely destroyed by the action of the sulphuric acid, the presence of which is explained by the frequent occurrence of iron pyrites in this bed.[1]

[1] See my paper on the Development and Subdivision of the Tertiary system in Burma; Records, XVIII, p. 59.

c. The occurrence of petroleum.—At Yenangyoung the upper miocene beds are of great economical importance, because of the petroliferous beds they contain, which have yielded, comparatively speaking, a large quantity of petroleum.

It has been proved to a certainty that in the Yenangyoung oil field the petroleum is always associated with the arenaceous beds, that is to say, the sandstone is always saturated with petroleum, while in no case is it present in the argillaceous beds, or, as might perhaps be expected, gathering in their fissures or cracks. The clay beds seem to act like a hermetic seal, as is well illustrated in all cases where native wells have just reached the upper part of the petroliferous sands. It seems that towards the top thin beds of clay alternate with the sand, which finally passes into clay. The sand is always charged with oil, and exhibited its fine green colour, while the clay contains no trace of it. I also frequently observed that when breaking a fair sized lump of clay and, as is often the case, it contained a lenticular thin layer of sand, this sand was often full of oil, although no trace of it could be seen superficially. I want to put stress on the fact that I did not observe this once, but repeatedly, and that I was very particular in verifying the correctness of this observation, which seemed to me of the greatest theoretical importance, inasmuch as it sheds a light on the origin of the oil. I may remark here that this mode of occurrence renders it impossible, that the petroleum should have originated at some other place and migrated to its present receptacle. It is impossible to imagine how it could have penetrated a fairly thick layer of clay without leaving the slightest traces of the way is followed, and eventually gathered in a sandy streak. If this view is taken, the question might well be raised why, if such a force existed, was not the petroleum again driven out from the sandy layer. To me this proof seems convincing that either the substances eventually changed into petroleum, or the petroleum itself must have already been absorbed by the sandy layers before the latter was hermetically sealed up and surrounded on all sides by a covering layer of clay.[1]

This instance of petroleum occurring in sandy layers, surrounded on all sides by clay, is repeated on a larger scale in the petroliferous sands, although it is very difficult to prove, in this case, their entire isolation and the absence of any communication with other beds. The deep wells have, however, given in some instances such a sequence of strata that it is impossible to interpret them in any other way, but that a, comparatively speaking, thick bed of sandstone is intercalated in and surrounded on all sides by argillaceous beds. The presence of the petroliferous sand 2 (*a*) in Wells No. 6 (*a*), 10, and 8, and its absence in all the surrounding wells, can hardly be explained in any other way except that it forms a lenticular arenaceous mass imbedded in clay. I may further add that I actually observed a thick bed of sandstone dying out in an argillaceous bed,—a subject which will be dealt with in a subsequent chapter.

To me it seems therefore beyond any doubt that the petroleum stored in the petroliferous sands in the Yenangyoung oil field must be indigenous, and that the assumption of an extraneous origin, and the migration to its present receptacle, is incompatible with the observed facts.

Whether, however, the view of the indigenous origin of the Yenangyoung oil field be accepted or not, the deep borings have proved that it occurs within the area of the Yenangyoung oil field in at least six different horizons. It may be almost considered as certain that the above number does not represent the total of the petroliferous sands

[1] It may be advisable to point out that this conclusion is not so fully established as Dr. Noetling's languages would suggest. The penetrating nature of mineral oil is well known, and as Mr. H. B. Medlicott wrote in 1886 (Rec. XIX, 191), "when we find geodes filled with successive layers of minerals in the midst of compact basalt it is difficult to place limits on the possibilities of permeation." Dr. Noetling's own observations on the connection between geological structure and distribution of petroleum in the Yenangyoung oil field indicate that the present differs from the original distribution of the oil; this, however, is compatible with the original inclusion of it, or the materials from which it was derived, in the beds in which it is now found—*Ed.*

contained in the Prome division, but unless proved by deep borings nothing definite can be said about it. It also seems quite certain that the different petroliferous sands vary greatly in horizontal extension, and that therefore complete sequences of the petroliferous sands are by no means found in every single well. In fact, the irregularity of horizontal extension has been one of the chief difficulties with regard to the correlation of the single beds observed in the different drilled wells. In the following enumeration the petroliferous sands are numbered in descending order beginning with the one nearest the surface.

1. *The first oil sand.*—The first oil sand is generally found immediately below the beds of the Yenangyoung stage, at depth varying from about 80 to 100 feet from the surface. Its thickness is never great, being about 20 to 30 feet, but locally it may increase somewhat. In the latter case it is very probable that the argillaceous bed, which elsewhere separates the first and the second sand, has disappeared, and both form a continuous stratum. Instances will be frequently noticed in the boring registers which indicate this probability. It is remarkable to note that the first oil sand contained only slight traces of oil in two of the northernmost wells, No. 21 and A at Kodoung, while in all the other wells it was unpetroliferous, being either dry only containing water. On the other hand it is quite certain that it contained a considerable quantity of petroleum within the Twingon and Beme areas, and only quite recently this has been proved by pit wells in the south-western corner of the Twingon area. The oil produced by this sand seems to be the heaviest oil, inasmuch as its average specific gravity is higher than that of any of the lower sands.

2. *The second oil sand.*—This bed is found at a depth of about 150 feet from the surface; its thickness varies, but it never exceeds 50 feet. As already stated, it is possible that in some parts of the oil field it forms a continuous bed together with the first oil sand. Like the latter it never contained any oil within the limits of the Kodoung tract excepting well No. 40, where a small quantity

of petroleum was found in a bed which may be correlated with the second oil sand. On the other hand it must have contained considerable quantities of petroleum to the north and south of Kodoung as there are still a good many of the pit wells which draw their oil from the second oil sand. As regards the chemical quality of the oil of this horizon, it is almost certain that it is on the average of lighter specific gravity than the oil from the first sand, although a little heavier than that of the fourth sand.

3. *The third oil sand.*—The independence of this layer seems questionable ; so far it has only been observed in few wells to the north of the Kodoung, such as No. A, No. 6, No. 8, in all of which cases it is separated from the next following fourth sand by a comparatively thin bed of clay, which renders it very probable that this layer only forms the top of the fourth oil sand, locally separated by an intervening bed of clay. In all cases it contained a considerable quantity of petroleum.

4. *The fourth oil sand.*—This is the bed which supplies the greater quantity of oil found at the Yenangyoung oil field. It has been generally found at depth ranging from 220 to 250 feet from the surface, but of course the depth must vary for different reasons ; and as regards thickness it varies so much that there are hardly two wells where it exhibits the same thickness ; it may not be more than 20 or 25 feet in one well, while it exhibits a thickness of nearly 300 feet in another. The reasons of this variation will be dealt with in another section. The fourth oil sand contains petroleum throughout the Yenangyoung oil field ; it seems that the oil from this sand is lighter in specific gravity than that of any of the upper sands, inasmuch as its average specific gravity is 0·8766 or 0·8921 at 60° F.

With regard to the deeper oil sands, it must be said at once that only the merest indications can be given, because only a few wells have reached a greater depth, and these wells are so far distant from each other that a correlation of the various strata observed seems almost impossible. The difficulty is particularly increased, because it seems that the various sands noticed in the different wells are most probably only parts of one and the same layer, separated by local argillaceous beds. It seems, however, certain that below the fourth oil sand there is a fifth layer containing petroleum, which most probably reaches a great thickness. It has been observed in wells No. 56, No. 51, No. 54, No. 60 and No. 59, but has not so far yielded a very large quantity of petroleum. Only in one well No. 54, but perhaps also in No. 13, a sixth oil sand seems to have been found below the fifth horizon, but no details can be given about its extension. As no samples of petroleum have been obtained separately from either the fifth or sixth oil sand, nothing can be said about the specific gravity of the petroleum they contain.

So far the few wells which went deeper than the fourth oil sand seem to have proved that the lower sands contain only a small quantity of petroleum. Whether this applies also to still deeper strata remains to be seen, and nothing definite can be said at present, and only an actual boring can decide.

It will be useful to record in this section a few more observations which are intimately connected with the occurrence of the petroleum. These are: The migration of the petroleum within the beds in which it is contained at present, and the relations between the occurrence of gas, petroleum, and water within the whole series and within a single bed.

Although the assumption that the petroleum has migrated from other places to the beds in which it is contained now, must be rejected for very strong geological reasons, it cannot be denied that a certain amount of migration must take place within the petroliferous bed itself. In fact, it would be difficult to believe that the petroleum remains in an absolute state of rest inside its receptacle. There are two facts which almost prove conclusively that a certain amount of movement of the petroleum must take place. These facts are—

(*a*) The periodical rise and fall of the production with the season.
(*b*) The continuity of the production of the deep wells.

(*a*) *The periodical rise and fall of the production during the* *year.*—If we note the months in which the maximum and minimum production took place, we see that it was recorded in :—

in 1886 the maximum was in	August,	the minimum in July.
1887 " "	" May,	" " March.
1888 " "	" May,	" " February.
1889 " "	" June,	" " January.
1890 " "	" July,	" " February.
1891 " "	" June,	" " January.
1892 " "	" September,	" " February.
1893 " "	" March,	" " February.
1894 " "	" December,	" " February.

We see that during the nine years over which the observations have extended, the minimum production has been noted eight times during the first quarter of the year; only once, in 1886, was it observed in July; as, however, 1886 was by no means a normal year, and as it is recorded that in July of that year oil was drawn only during about 20 days, we may disregard this observation as unreliable. The maximum production was noted seven times out of nine during the months May to September, namely, twice in May, twice in June, once in August, July and September, it was only once noted in March, and once in December, but it may be added that in both years the maximum noted only slightly exceeded the production of the months of July and May respectively.

To make the matter clearer still I have computed the average production of each month of the year, which is as follows:—

January	564,498	viss.
February	520,372	"
March	566,719	"
April	535,312	" *
May	591,984	"
June	642,890	"
July	664,653	" †
August	645,233	"
September	611,532	"
October	622,608	"
November	633,222	"
December	596,214	"

* April 1891 has been disregarded as an anomalous month.
† July 1886 ditto ditto ditto.

(114)

The above figures prove distinctly, as will be more readily seen from the diagram fig. 2, that there is unquestionably a periodicity of production, which is intimately connected with the season. The

Fig. 2. Diagram showing the mean monthly yield of petroleum from 1886 to 1894.

year begins with a comparatively low production in January, which is followed by a quick drop in February, and a sudden rise in March, after another drop in April, the production quickly rises till it has reached its maximum in July, a rather sudden, but not large, drop takes place up to September, when it again slowly rises till November, only to fall largely and suddenly in December, a drop which lasts till February. Now, is it a mere coincidence that the curve, as above depicted, represents in some rough way the line illustrating the rise and the fall of the Irawadi? Unfortunately no exact observations regarding the river gauge have been made at Yenangyoung, but experience has proved that the river reaches its lowest level in February, a small rise takes place in March, probably owing to the snow water coming down from the upper regions of the catchment area, and then another fall takes place in April. From May the river rises until it has reached its maximum level during the months of June, July or August; it falls slowly till November, but thence to February the fall is quick and considerable.

To me it seems obvious that there exists a connection between the height of the river level and the quantity of the production of the native wells, and, as I have already pointed out, that there is a relation between the activity of the mud volcanoes and the height of the river (see page 44), it is not unreasonable to suppose that the same influence which stirs up the mud wells affects the petroliferous sands in such a way that the discharge of the oil is more abundant during the rainy season than during the other months. The production of the drilled wells exhibits the same phenomenon, although it is here not so conspicuous for reasons which are easily explained. In the pit wells the oil slowly filters into the well, there to gather, while it is pumped out in a permanent stream from the drilled wells. Probably, therefore, the quantity obtained from the latter does not represent the quantity which would be obtained if the oil were allowed to collect slowly in the bore hole, as in the pit wells.

The explanation of this strange phenomenon is by no means easy because we know unfortunately little or nothing with regard to the movements of liquids in rocks at considerable depths, and under considerable pressure. We may, however, at once dismiss the theory of the influence of the temperature; quite apart from the fact that the temperature is usually highest when the production is lowest (February to April), it is almost certain that the beds which supply the oil are beyond the yearly range of the changes of temperature on the surface.

But perhaps the following theory will afford an explanation. It seems very probable that the petroliferous series is intercalated in an arenaceous formation of considerable thickness, permeated by water. We further know that the chief oil producer, the fourth oil sand, is found at a depth which differs not materially from the high water level of the river. I believe we may safely assume that when, during the rains, the river rises to sometimes fifty and more feet above its low water level, the ground water will also rise, and this in its turn presses on the petroliferous sands and forces the oil to flow more freely.

However that may be, it is beyond doubt that the oil flows more freely during certain months of the year, and this can only be explained by the assumption of certain currents existing in the oil sand.

(*b*) *The continuity of production of the drilled wells.*—It is most remarkable that although some of the drilled wells are over six years of age, their production has not become less. If these wells derived their supplies from only a limited area they would have already shown signs of exhaustion. The steady production of the wells seems to indicate that the oil which is taken out is immediately replaced, and this involves the assumption of the existence of a current of oil which is moving towards the deep wells.

(*c*) *Relations between the occurrence of water and petroleum.*—With regard to the general relations between the occurrence of water and that of oil within the area of the Yenangyoung oil field, the deep wells have revealed some facts, which do not seem to be quite compatible with the theory that we should have gas at the highest points of the anticlinal, oil in the centre, and water below. Whatever may be the value of this theory for localities, it does not seem to hold good for the Yenangyoung oil field, where there is apparently an irregular distribution of the above named three substances throughout the series. I must, however, put stress on the words throughout the series, as it is quite possible that the theory holds good within the compass of one and the same bed. It seems certain that within the same bed the oil always seeks to rise to the highest points because the most prolific wells are unquestionably situated at such points where the petroliferous beds have risen highest above the sea level, and it is also certain that whenever petroleum and water are associated in one and the same bed, the former always rises above the water, with the exceptions of wells No. 48, No. 61 and No. 54, where it has been stated that water sand was found on the top of the oil sand without being separated from it by an argillaceous parting as it is generally the case.

The boring record of well No. 48 is—

40	feet	blue clay	from	165 to 205	feet.
35	,,	water sand	,,	205 to 240	,,
115	,,	oil sand	,,	240 to 555	,,

Unless we assume that there must be an argillaceous parting between the water and oil sands the case is remarkable. The instance of No 54 is even more striking; the boring record states—

25	feet	blue clay . .	from	400 to 425 feet.
75	,,	grey water sand . .	,,	425 to 500 feet.
175	,,	dark sand . .	,,	500 to 675 ,,
50	,,	oil sand with slight show of oil	,,	675 to 725 ,,
15	,,	of blue clay . . .	,,	725 to 740 ,,

Provided that this record is correct, we would therefore have a continuous arenaceous series of an aggregate thickness of 300 feet, containing water at the top, being dry in the middle, and petroliferous at the base, inclosed between impermeable beds of clay.

With regard to No. 61, the case is stranger still; some 60 feet of white sand, with some water rest on the top of 100 feet of oil sand, without apparently a separating medium; the oil sand in its turn rests on 5 feet water sand. If this boring record is correct, we would have an arenaceous series of more than 165 feet in thickness, a layer of petroleum in the middle, and a layer of water on the top and at the base which seems to be so contradictory to all laws of specific gravity, that for the present I must record it with some doubts.

With regard to the distribution of water and petroleum through the series, it is quite certain that they occur quite independent of each other; but that in this case the petroliferous and water bearing beds are always separated from each other by impermeable beds of clay. It would be useless to go into details at length, a glance at the sections or at the boring records will prove this, but still I may be permitted to mention the two deep wells, No. 13 and No. 54, in greater detail. In No. 13 the following sequence of water bearing, petroliferous and argillaceous beds has been recorded in descending order—

104	feet of sand	. . . . .		Yenangyoung stage.
49	„ shale and clay	. . . . .		
48	„ water sand	. . . .	(1)	Prome stage.
95	„ clay	. . . . .		
87	„ oil sand	. . . .	I	
28	„ water sand	. . . .	(2)	
64	„ shale and clay	. . . . .		
3	„ water sand	. . . .	(3)	
42	„ shale and clay	. . . . .		
121	„ water sand	. . . .	(4)	
14	„ shale and clay	. . . . .		
5	„ water sand	. . . .	(5)	
70	„ clay	. . . . .		
15	„ water sand	. . . .	(6)	
35	„ shale and clay	. . . . .		
13	„ oil sand	. . . .	II	
3	„ shale	. . . .		

The above record proves the existence of at least five successive and independent arenaceous beds, varying in thickness from 3 to 121 feet, which are saturated with water. The second bed forms probably part only of the bed containing petroleum at the top. Between these water bearing strata two petroliferous beds have been found, the first of which is overlaid by only one stratum containing water, while all the rest are above the second oil sand. We notice, however, that in every instance impermeable argillaceous beds separate the water bearing and petroliferous strata, and that it is remarkable how a comparatively thin bed of clay forms an effectual separation.

The record of well No. 54 is equally interesting, although it represents an anomaly which has already been mentioned. The following is the sequence in descending order :—

80	feet surface sand.		
20	„ blue clay.		
60	„ black sand	(1)	
15	„ grey water sand.	(2)	
100	„ blue clay.		
125	„ dark sand with slight show of oil, and water		I.
25	„ blue clay.		

75	feet	grey water sand	(3)
175	„	dark sand	(4)
50	„	oil sand with slight show of oil . . II.	
15	„	blue clay.	
20	„	grey water sand.	(5)
40	„	blue clay.	
25	„	oil sand with slight show of oil . . III.	
25	„	blue clay.	
20	„	grey water sand	(6)
30	„	tough blue clay.	
30	„	white sand	(7)
20	„	blue clay.	
10	„	black sand	(8)

If we assume that the black sand differs from the grey sand, and there is no reason for any other conclusion, we notice eight different sands, four of which are water bearing, four apparently dry; while distributed between these, there are three petroliferous sands. With the exception already mentioned, they are, however, all separated from each other by beds of clay.

Another feature must be mentioned; there is no doubt that one and the same arenaceous bed has been found to be water bearing in one well, while it was dry in another. It even seems, if I rightly interpret the boring registers, that the first and second oil sands are unproductive at Kodoung, while they certainly contain oil at Twingon and Beme. We may even go a step further and say that some of the wells like Nos. 64 and 68 seem to indicate that the same bed, which yields oil elsewhere, contains only water in these wells.

The first observation is not easily explained, unless it be by the rise and fall of the ground water. We may suppose that its level rises and sinks, and when it is high, water is found, in one and the same bed, at a higher level than in a well close by, where the same bed is said to contain no water, because the boring was made when ground water stood low. Unfortunately it is not easy to ascertain from the boring registers how far this supposition is borne out by facts, and as eventually the bore must be tubed to shut off the water found, perhaps at a greater depth, it is impossible to say whether a certain higher bed, which was dry at the time when it was drilled through, contains water during other seasons of the year.

The second feature is more easily explained; we may well imagine that, with the gradual removal of the oil from the petroliferous sands, the water gradually rose under the hydrostatic pressure and replaced the oil. As the two wells above mentioned have been drilled near the margin of petroliferous tract, such a supposition is by no means improbable.

As the last feature in the occurrence of oil, we have to deal with flowing wells and the presence of gas. That gas emanates from the petroleum can be easily seen in the wells, in some of which the evaporation of gas is so rapid that the surface of the pool of oil gathered in the well is in an agitated state, as if boiling, and gas bubbles are incessantly rising. No gas pressure worth speaking of has been observed in any of the drilled wells, although there is unquestionably a small pressure, but insufficient to produce flowing wells. With regard to this the Yenangyoung oil field has not proved a success, and all the oil must be pumped from the wells; as far as our present experience goes it is also very unlikely that flowing wells will be found within the limits of the Yenangyoung oil tract.

In conclusion a few words must be said about the curious occurrence of gas recorded in wells Nos. V, VI and VII just at the southern limit of the Beme oil tract. In No. V two consecutive beds containing gas were found, the upper between 91 and 205 feet from the surface, the lower at 286 to 330 feet; in No. VI the gas vein was struck at 255 feet, and in No. VII at 355 feet from the surface. The presence of gas just at this part of the oil tract, that is to say, its southern limit, is not easy to explain, particularly if we recollect that the gas is found here at a lower level than the oil in the other parts, unless we assume that the sand containing gas represents the fifth oil sand of the other deep wells. The only manner by which the presence of gas at this part of the oil field could be accounted for is the theory of the intersecting folds, which will be discussed in a subsequent chapter.

We may now sum up in a few words the facts which have been ascertained with regard to the occurrence of petroleum in the Yenangyoung oil field. These are:—

1. The petroleum is indigenous to the strata in which it is found.

2. The petroleum is restricted to the arenaceous beds, and tends to rise within them to the highest points.

3. Whenever water and petroleum are associated in the same bed, the petroleum generally rests on the water. There seem however to be a few instances, which would point to an exception to this rule, although they are not quite authenticated, and open to doubt.

4. Throughout the series water and petroleum may occur independently in different beds, following each other vertically, but in this case they are, with few exceptions, well separated from each other by impermeable beds of clay.

C. *Local subdivision of the lower miocene or Prome stage.*—The Prome stage being almost exclusively known from deep borings, it would be rash to attempt any general subdivision of this sequence of beds, which are all so much alike in their lithological characters; but fortunately we have a horizon, containing some very characteristic fossils, among which *Anthracotherium silistrense* takes the most prominent place. As this species has not yet been discovered in any of the higher beds, it may perhaps be admissible to designate the upper Prome beds as the horizon of *Anthracotherium silistrense.*

In going through the boring registers anything like a general subdivision of the beds recorded seems an almost hopeless task. It is impossible to subdivide a series of an approximate thickness of 1,100 feet, which consists of nothing but beds of clay and sandstone with no further distinguishing characters. The difficulty is still further increased by the fact, that the beds composing the petroliferous series were deposited in a most irregular manner, and that in the same level a sudden change from sandy into argillaceous beds often takes place within a distance of a few feet (see page 78).

All that we can therefore do under these circumstances is to investigate whether a certain sequence of beds can be recognized in the boring registers which, with restrictions, may hold good for the area of the Yenangyoung oil field ; but this will be discussed together with the sections of the deep wells.

SECTION 3.—STRATIGRAPHY.

A—General Features.

(*a*) *Unequality of sedimentation.*

Local unconformity and contemporaneous erosion.—One of the most remarkable features of the oil field is the great inconstancy of the strata. Only in very rare instances can a bed be followed for a few miles, and even within that short distance it undergoes rapid changes in its character, which renders it often extremely difficult to be recognized.

In the Aungban-yo or in the Ayatpo-yo good illustrations of complete thinning out of beds may be observed. On the northern slope of the former a bed of bluish somewhat sandy clay appears quite suddenly within a series of sandstone ; it attains very quickly the considerable thickness of 50 feet within a few feet, and then rapidly thins out, disappearing towards east and north under younger beds ; its final termination is not seen. The section exhibited in the Aytapo-yo shows this feature still better. The bed just mentioned is represented at its southern end by thinly laminated bluish clay alternating with sandy strata, where its top is about 50 feet above the bottom of the ravine. Proceeding northwards it dips slowly in that direction until it disappears, and is replaced by a series of soft, whitish or red sandstones in irregular thick banks, which contain at least four distinct beds of bluish clay, trace-able for a considerable distance. The lowest of these beds, about 5 feet thick, is separated from some bluish shales by a bed of white sandstone of 6 to 7 feet in thickness; it begins quite close at the southern end of the ravine, quickly attains its greatest thickness, and then runs as a very regular band, following the general dip towards north, until it disappears. About 30 to 40 feet higher up two other argillaceous bands appear, one near the southern, the other towards the northern end of the gully ; both begin as very thin beds, which quickly increase in thickness, but thin out completely further on. A very good instance is however the last bed, which has a maximum thickness of about 20 feet, while for a considerable distance it is reduced to a parting of about 2 inches. It begins as usual as a thin layer, which quickly swells and then thins out, forming a thin, hardly preceptible layer, once more suddenly swelling out to a thickness of about 25 feet; this continues a short distance to die out gradually (see plate IX).

Another very good illustration of the sudden change of argillaceous to arenaceous beds, within the same level, may be seen at one of the ravines on the western side of the Twingon oil tract, between wells No. 159 and No. 161.

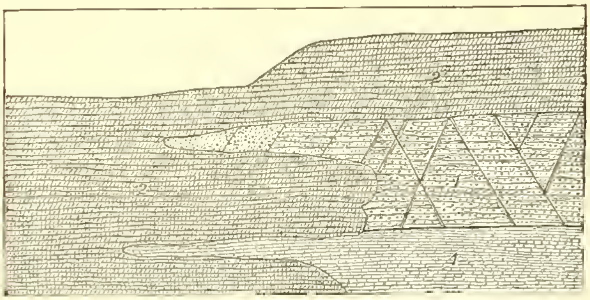


Fig. 3. Diagrammatic section showing the sudden change from arenaceous to argillaceous beds, between wells 159 and 161.

As will be seen from this diagram, there is near the right a bed of about 10 to 15 feet of reddish soft sandstone (1) exhibiting two sets of joints. This is followed by about 6 to 8 feet of well stratified bluish clay (2) which forms the surface, and is quite conformable to the sandstone. The sandstone terminates suddenly, and is replaced in the same level by bedded clay; higher up the sandstone continues some distance further, but it soon disappears entirely, and near the left of the section nothing but a bed of well stratified clay is seen.

From these few instances it will be seen how utterly impossible it is to identify correctly the different beds recorded in the deep wells.

This is, however, not the only difficulty which impedes a correct interpretation of the boring registers. There are two more of no small importance, *viz.*, contemporaneous erosion and consequent local unconformities within the series of the petroliferous beds. The best instance of these two features is shown in a section in the Aungbanyo just below the drilled well No. 38 which is reproduced on plate IX, and the most interesting part of which has been constructed on the base of very careful measurements in the following diagram.

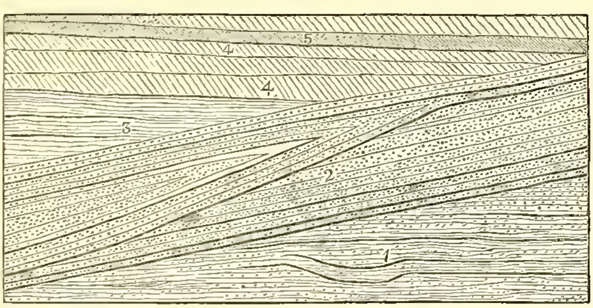


Fig. 4. Diagrammatic section showing double unconformity above the first oil sand in the Aungbanyo.

The series begins with a fine, rather hard, sandstone of grey colour slightly tinged reddish (1). The bedding of this sandstone is to all appearances perfectly horizontal, a feature which is rendered very conspicuous by thin partings of greenish clay. A bed (2), of about 4 feet in thickness, rests unconformably on this sandstone, formed by an alternation of thin, extremely regular beds of clay, and somewhat thicker beds of sandstone, none of the layers exceeding a few inches in thickness. These beds form an angle of $11\frac{1}{2}^{0}$ with the beds of the lower sandstone (1).

It is followed by a series, about 40 feet in thickness, of alternating beds of sandstone and clay, being again apparently horizontal; it begins with a layer f sandstone (3), similar in appearance to bed (1), which is followed by bands of very hard sandstone (4) and bluish clay (5), each of which successively overlap the lower beds.

This section proves in my opinion two points, *viz.*:

(*a*) A contemporaneous erosion.
(*b*) A double unconformity.[1]

Another instance of contemporaneous erosion is illustrated in figure 7, although it is here not so distinctly seen as in the former, being affected by some features presently to be mentioned.

It may be fairly supposed that within the petroliferous sands similar features often occur. In fact, I believe, that bed (1) in the above diagram represents either the first or the second oil sand, and that as a consequence their importance as a receptacle of the petroleum has been affected. On the other hand we see that under such circumstances it is almost impossible to correlate the petroliferous sands throughout the oil field, if we have no other feature to guide us than the petroleum which they contain.

(*b*) *Veins of eruptive mud.*—It is one of the strange features of the Yenangyoung oil field, that although the strata were subject to folding, that this has not led to dislocations worth speaking of. There is, of course, a certain amount of faulting, but the biggest throw which I have observed amounts to less than 50 feet, and even this is not quite clear. If any dislocations have taken place, they generally do not exceed a few feet, and remain quite local. On the other hand

1 The word unconformity is here used in a different and less significant sense than is usual in English Manuals of Geology.—Ed.

there is a good deal of fissuring, particularly towards Beme, but the fissures intersect the strata without, in most instances, producing faulting. The diagram and plates exhibit numerous instances of a series of beds being intersected by a fissure, without otherwise being disturbed by it. Diagram fig. 7 affords a very good instance of a vein (*a*) which traverses a succession of beds at a very high angle, without producing any dislocation.

These veins are mostly filled by either gypsum or fine mud between which there is probably some genetic connection.

The gypsum veins are filled with an argillaceous gypsum, arranged in layers, parallel to the walls of the vein, and of darkish brown colour. They are generally very hard and stand out in the form of a reef from the surrounding softer strata. So far they afford no particular interest, while the mud veins possess a great theoretical interest.

My attention was first roused by the peculiar appearance of certain beds of clay imbedded in the regular sequence of the series at the northern part of the oil field. The clay did not exhibit any signs of being stratified, nor was it homogeneous ; it consisted of a mass of fragments of clay, which apparently were removed from some other beds, mixed with a few hard concretions ; the whole mass was apparently horizontally spread out. At first I felt inclined to interpret it as a bed of clay pebbles such as may frequently be observed where a tenacious clay is exposed to the action of waves. When surveying the southern part of the oil field, however, the true explanation was at once found ; these beds represent nothing else but true eruptive mud. Before discussing these horizontal beds of eruptive mud, it will be useful to examine and describe those sections which exhibit the best instances of eruptive mud in veins.

As already mentioned, the finest instances can be seen in the southern part, particularly along the Taungle ravine, which is nearly everywhere intersected by mud veins. The best section is figured on plate VIII, and part of it has been enlarged and reproduced in the following diagram. We see here a series of perpendicular or

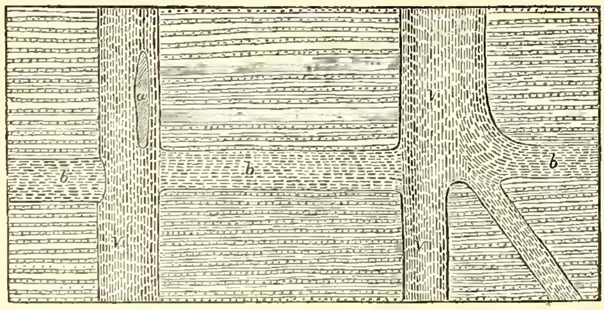


Fig. 5. Diagrammatic section showing the intersection of perpendicular, horizontal and diagonal veins of eruptive mud in miocene sandstone, Taungle-yo, east of Beme village.

highly inclined veins which intersect a fine soft sandstone, filled with clay, or rather fine mud. The structure of the material proves clearly that it must have been forced up into the fissures, completely filling them. The mud consists of a mass of fragments of sometimes well stratified clay, which are arranged in lines roughly parallel to the walls of the vein. It is quite evident that the surface of these clay fragments must have been moist and in a more or less soft state, thus allowing them to be compressed into a homogeneous mass, while still preserving their individuality in the core. If the expression may be allowed, these mud veins exhibit a porphyritic structure. Frequently hard concretions are imbedded, like (*a*) in figure 5. For a certain distance from either side of the walls the mud is usually more or less impregnated with a whitish alkaline substance.

In the above section the perpendicular veins intersect horizontal ones of the same structure, and in one instance at least it is quite clear that they must have passed through the horizontal beds producing sometimes a small dislocation. In the majority of the cases the substance of the horizontal and vertical veins has been so intimately anchylosed that it appears as if the horizontal beds were continuations of the vertical veins, injected into the surrounding beds. There is no doubt with regard to this mode of occurrence at another section, but in this particular instance it is quite clear that the horizontal beds (*b*) existed before the vertical veins (*v*) passed through them.

As to the shape of the veins themselves there is not much to be said; they apparently represent a network of fissures varying from the thickness of a sheet of paper to about ten inches. The veins remain sometimes independent, two or more may join, or lateral offshoots may branch off and continue to run as independent veins.

Another and perhaps better illustration of this feature is the occurrence of mud veins near well No. 510 in the Beme part of the Yenangyoung oil field represented in the following woodcut. We see here an almost horizontal bed of eruptive mud (*a*) imbedded in

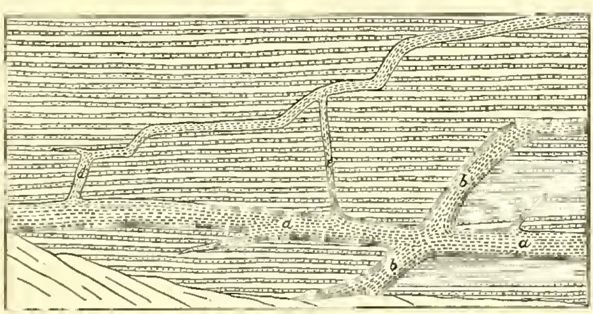


Fig. 6. Diagrammatic section showing diagonal veins of eruptive mud in miocene sandstone, near well 310.

soft, horizontally stratified sandstone. This mud deposit sends off several offshoots, of which (*b*) may perhaps be doubtful, whilst (*c*), (*d*), and (*e*) are good examples of such veins. The offshoots (*c*) are particularly interesting, as they exactly resemble the apophyses of an intrusive rock and are unquestionably injected into the surrounding matrix.

The most interesting offshoot is however (*d*). It branches off the main vein at about 70°, keeps to that direction for about 3 feet, then suddenly forms a knee, and follows the bedding of the sandstone, sending off a short apophysis in the opposite direction; it remains quite conformable to the bedding of the sandstone for about 3 feet then turns up again, passes into a higher level, where it again follows the direction of the bedding for some distance and then traverses the sandstone to the surface. About 33 feet from the point where (*d*) originally branched off from (*a*) both are joined by a vein of only 2 inches in diameter which shoots off at an almost right angle from (*a*) and joins (*d*) about 8 feet above (*a*). It is not quite certain whether the branch (*b*) is also a diagonal offshoot of (*a*), or whether it is an independent vein, merely traversing (*a*); its continuation towards a lower level seems to indicate the former, but this may also be merely an apophysis like (*c*) only somewhat stronger. However, whether independent or not, this does not in any way affect the structural importance of the veins here described. It may be remarked that this section was exposed at one side of the deeply cut road leading to well No. 510, whilst no signs of the veins were exhibited on the opposite side of the road.

The mud with which the veins are filled exhibits its usual lumpy structure. It may be remarked that at one part of (*d*) it contains so much of alkaline salt, that its appearance is very similar to the gypsum veins.

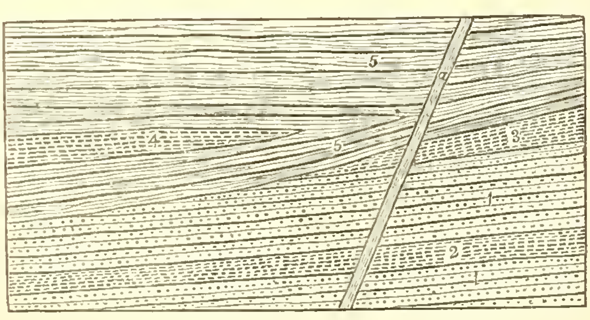


Fig. 7. Diagrammatic section showing unconformity and horizontal veins of eruptive mud in upper miocene sandstone, near wells Nos. 530 and 541.

Another very illustrative section, represented in figure 7, is seen near wells No. 530 and 541 in the same part of the oil field. In a series of fine hard sandy beds alternating with beds of sedimentary clay, we find here a bed (2) which represents all the characters of eruptive mud; higher above another bed (3) which, notwithstanding the unconformity above it, unquestionably represents the termination of a bed of eruptive mud. This is followed by a series of rather hard sandstones, alternating with thin beds of clay, into which is injected a horizontal vein of eruptive mud.

I could easily increase the number of instances, but they all illustrate the same features; perhaps I might mention a large lump of sandstone, which had apparently been crushed, and its fragments recemented by the eruptive mud which filled the cracks, but this only represents on a smaller scale what is already shown in plate VIII.

We find beds which thus exhibit all the characters of eruptive mud imbedded in the regular sequence of the strata.

It is most probable that eruptions of liquid mud took place during the deposition of the strata between which we find the mud streams conformably intercalated.

All the evidence available leads us to believe that eruptions of mud took place during the formation of the upper Prome and probably also of the lower Yenangyoung stages. This mud spread out in horizontal layers and was thus inclosed in the regular series. We may suppose that subsequently the series of beds was rent by innumerable fissures, through which mud was pressed up, passing through the original horizontal layers.

As regards the occurrence of these veins I found them in the upper Prome and also in the lower Yenangyoung stages. So far none were noticed in the upper parts of the Yenangyoung stage, while it is certain that they do not occur in the Irawadi series. This seems to me of a great theoretical importance, to which I shall revert in a subsequent chapter; but it may be mentioned here that up to now I have only observed these veins within the Yenangyoung oil field.

The anticlinal and dome-like structure.—The late Dr. Oldham, when visiting Yenangyoung in 1855 had already noticed that the oil fields were situated on the crest of an anticlinal flexure; he simply mentions the fact, without any further theorizing. In 1888 I was able to fully confirm Dr. Oldham's observations and to give some details with regard to the structure of the anticlinal arch. After the topographical survey had given the basis for a trustworthy geological map, a new structural feature was discovered. The peculiar mode of outcrop of the zone of *Hippotherium antelopinum*, proved that it was not only a simple anticlinal arch, but that the general structure of the Yenangyoung oil field was that of a low dome or "turtle-back" fold.

aa. The anticlinal arch.—The anticlinal arch formed by the tertiary strata at Yenangyoung is comparatively flat and broad, in consequence of the low angle of dip of the strata; nowhere does this exceed 40°, and even such a high angle has only once been noticed on the eastern side of the anticline. The angle of dip decreases towards the centre of the anticline. In passing over the arch from west towards east we see the angle of dip of 37° to 38° on the bank of the river gradually becoming flatter till the axis of the anticline is reached, where the strata appear horizontal for a short distance; after which the angle of dip again gradually increases till it reaches its maximum of 39° to 40°, which it keeps on as far as I have examined the country.

The anticlinal arch appears therefore almost symmetrical, but it is quite certain that it dips slightly steeper towards the eastern side. The direction of dip is very regular and generally south-west on the western and north-east on the eastern side. It varies slightly of course, and its magnetic bearing may be said to oscillate between 60° to 68° west of south or east of north.

Necessarily the direction of the strike varies also, and its direction ranges from 325° to 330,° but within this range it keeps the direction very steadily.

bb. The longitudinal arch.—I understand under this term the low arch which is formed by the strata in the direction of the axis of the anticlinal. As already stated, its presence was first discovered after mapping the Yenangyoung oil field; the presence of such a dome shaped anticlinal was made apparent only after mapping the outcrop of the zone of *Hippotherium antelopinum*.

This zone forms a well marked horizon in the sequence of the strata, and crops out in the shape of an elongated ellipse, the long axis of which measures two and a quarter miles, while the short (transverse) axis amounts to slightly over a mile only.

It was desirable that the view thus theoretically obtained should be confirmed by actual observations, if possible. It is of course obvious that observations of this kind require the greatest care,—in fact to be of any value, they could be only carried out strictly along the axis of the anticline; but even then it will be seen that, from what I have said above with regard to local unconformities and the inconstancy of the beds in horizontal direction (see page 78), the possibilities are that the natural dip of the longitudinal arch may be obscured by these features, and at any rate great difficulties were to be expected in ascertaining facts with regard to its existence.

However, I carefully examined the Yenangyoung oil tract, specially with regard to the longitudinal arch, and the following are the observations which I have made. South of Beme, particularly along the Maung Aung Gyaw The-Yo, and to the north of well No. I, the beds exhibit a distinctly southerly dip along the longitudinal axis of the anticline, which, however, and this is the remarkable part of it, seems to be limited to a certain restricted area, north, south and west of which the strata exhibit their regular western dip. In this case it is not quite certain whether this southern dip is not due to a local sliding of at least a part of the upper beds on the soft clay below; it may also be that the southern dip indicates the presence of another structure presently described as intersecting folds. The ground however was not favourable for further examinations, neither was it in the Beme or Kodoung oil tract, owing to the direction of the ravines.

More favourable was the direction of the Ayatpo-yo, at the southern part of the Yenangyoung oil field and the adjoining slopes of the Aungban-yo. The Ayatpo-yo cuts the petroliferous area in an almost longitudinal direction, and it was therefore expected that if any dip either in northern or southern direction did exist, it would show here.

The view plate VIII, will distinctly show that the bluish shales exhibit a most marked inclination of about 7 to 8° towards north, an observation which has also been confirmed at the southern part of the Twingon oil field, where the same bed comes to the surface. The same inclination is followed by the lower beds of the Yenangyoung stage, although much of it is counteracted higher up by the irregularity of thickness of some of the beds. But on the whole a most distinct northern inclination was noticeable.

On the northern slope of the Aung-ban-yo it seemed as if there was a slight southern inclination, although this could not be ascertained owing to the beds not being well exposed.

Towards the northern end of the Twingon tract a northern dip was observed, but in this case it is not quite clear whether this is not due to an altogether different structural feature presently to be described.

It is on the other hand quite certain that, further towards north near the Pin-choung, the surface of the zone of *Hippotherium antilopinum* exhibits the most distinct northern dip.

Although very scanty, these few observations are sufficient to support in a great measure the theoretically deduced view of the existence of the longitudinal arch. In the southern part of the field, where a southerly dip is required, we notice a southerly dip, and in the northern part, where a northern dip is required, we notice a most distinct northern inclination which could not entirely be hidden by the irregularities of the sedimentation.

We may therefore assume that it is unquestionably proved that the structure of the Yenangyoung oil field is in the shape of a dome-like anticlinal, but before attempting to explain the formation of this feature, it will be useful to describe the sections as observed on the surface and then to discuss the sections from the deep borings.

B.—The Superficial sections.

In order to get at a fair idea of the transverse structure of the Yenangyoung oil field, I have constructed five cross sections, one occupying about the middle and two to the north and south of it. It was fortunate that the chief direction of the natural drainage runs across the anticlinal arch, and thus the main ravines afforded an exceedingly good opportunity for the study of the sequence of the strata and their structural features. It will be seen that the Irawadi series and Yenangyoung stage are chiefly exposed, while the topmost part of the Prome stage is only seen along a short distance in three of the sections. Although not much can be said about the sections which has not already been stated before, it will be useful to explain each with a few words.

SECTION NO. 7 (PL. XIV) FROM KYUNBODOUNG TO THE PINCHOUNG.

This section exhibits the series of strata observed north of the Yenangyoung oil field, at that particular part where the zone of *Hippotherium antilopinum* is preserved in the centre of the anticlinal. Beginning at the western boundary line, the beds of the Yenangyoung stage extend along a horizontal distance of about 3,500 feet towards the east, and represent a thickness of about 2,200 feet, dipping at about 25° to west, then follows the zone of *Hippotherium antilopinum*, with a thickness of about 25 feet, and below it, but very badly exposed, are the top beds of the Yenangyoung stage. Passing the centre of the anticlinal the zone is again met with, but now it dips towards east, followed by the Irawadi series, dipping at about 25°.

SECTION NO. 6 (PL. XIV) ALONG THE POUNGKA-DAW AND NATSIN RAVINES; NORTHERN END OF THE YENANGYOUNG OIL FIELD.

On the western side of the anticlinal, the zone of *Hippotherium antilopinum* is found at 1,716 feet from the boundary of the map and from here to the point where it is again seen on the eastern side is a distance of 5,100 feet where the beds of the Yenangyoung stage may be seen, and right in the centre a bluish grey bed is exposed, which must be considered to represent the Prome stage.

SECTION NO. 5 (PL. XIV) ALONG THE AUNGBAN-YO (SOUTHERN SIDE OF THE TWINGON RESERVE).

This section is of interest, because the upper Prome stage apparently rises here highest above sea level, occupying in the shape of bluish grey shales and sandstones, about 1,320 feet in a horizontal line, near the centre of the anticline.

SECTION NO. 4 (PL. XV) ALONG THE NORTHERN BRANCH OF THE BEMECHOUNG (KHUNNHITSE-YO).

It is quite evident that in this section the level of the top of the Prome stage is less elevated above sea level than in the former section, while the Yenangyoung stage shows no decrease of its superficial exposure.

SECTION NO. 3 (PL. XV) ALONG THE SOUTHERN BRANCH OF THE BEMECHOUNG (TOUNGLE-YO).

The top bed of the Prome stage is here still exposed in the central part, but it will be noticed that the distance between the zone of *Hippotherium antilopinum* on either side of the anticlinal has decreased to about 4,400 feet.

SECTION NO. 2 (PL. XV) ACROSS MINLINDOUNG TO YEDWIN-AING-YO.

In this section the Prome stage has entirely disappeared; the Yenangyoung stage is badly exposed in the centre, but we see that the zone of *Hippotherium antilopinum* forms a continuous layer interrupted by erosion at two localities only, stretching from west along the slopes of Minlindoung towards the east, covered by beds of the Irawadi series. The dip on the western side is about 30°, but it becomes flatter and flatter towards the centre forming the reverse on the eastern side.

These sections prove conclusively that the angle of the arch of the anticlinal changes in proceeding from the south towards north; it is very flat near Minlindoung, but becomes more and more compressed towards the middle of the oil field, whence it again slowly flattens out. The natural consequence of this change in the arch of the anticlinal must be a rise of the crest from its southern end towards the centre and a fall from thence towards its northern end. The lateral pressure which has produced the anticlinal did not act equally throughout its length: at some places it acted more forcibly, at others with less energy. At the former places the beds were more compressed than at the latter, and naturally deeper strata were raised closer to the surface than it was the case at places of smaller energy in the lateral pressure. The natural result of this different energy must be the production of a dome or turtleback-like elevation, the slope of the surface of which is directly proportional to the energy of the lateral pressure.

C.—The sections of the drilled wells.

From the records of strata, as found in the deep wells, as I received them from the boring engineers, I have constructed the sections on plates XIII, XIV, making allowances for the level of each well, in order to obtain as accurate a position of each bed above sea level as possible. A few words must, however, be said about the great difficulties in the way of comparing these boring registers, when there were no other means of identifying and correlating certain beds but such vague terms as have been used by the drillers, and the depth at which such beds were found from the surface. It is also almost certain that the various drillers have used slightly different terms to designate the lithological character of one and the same bed, a discrepancy which of course increased the difficulties still more.

A glance at the boring registers shows how almost hopeless it is to introduce order into this confused mass of details. The chief difficulty is due to the similarity of the strata met with. There is no lithological difference between two samples of clay, the one coming from near the surface, the other from, say, 1,000 feet depth, and the same remark applies to the arenaceous beds. No fossils having been found in any of the beds, we are therefore unable to identify the strata found in different wells. The task is rendered the more difficult, because certain features, which will be dealt with in a subsequent chapter, indicate a very peculiar structure of the Yenang-young oil field. If we further consider that the vague terms which the drillers used to designate the beds, such as "shale," "slate" and "clay," may in one case all mean one and the same argillaceous bed, while in other cases they really represent lithological differences, it is obvious that a fairly accurate identification of the strata found at different places by different men and at different times, recorded in varying terms, is almost hopeless. After carefully comparing the above records one feature was, however, very conspicuous; immediately above the sand which chiefly produces the oil there is a bed of clunchy clay which seems of particular tenacity.

The fact was also established that within certain limits this bed occupies a remarkably constant position above sea level. Thus an important horizon has been established, the beds above and below which can be considered separately. I must mention, however, that in some cases the identification of this bed is not absolutely certain, and the boring records may therefore be interpreted in a way different from the one I have suggested in the sections constructed on the strength of the boring registers. I do not think, however, that this will materially affect the theoretical conclusions deduced therefrom.

It is extremely difficult to say whether the beds thus distinguished, and succeeding each other vertically, represent true geological horizons or not. In fact there is sufficient evidence to believe that some of the minor beds represent but local horizons within the stratigraphical series. With the above restrictions I have adopted the following sequence of strata:

(*a*) Immediately below the Yenangyoung stage follows a thin bed of blue clay which apparently represents the upper portion of the Prome stage. So far this bed has only been found in well No. 55. It is extremely difficult to say whether this bed is also represented in such wells as Nos. 3, 8 or 36, where a sequence of very thin beds of clay alternating with sandstone has been found immediately below the Yenangyoung stage which is usually designated as "shale." The probability is decidedly in favour of this view.

(*b*) Below the above bed follows the first oil-sand, which contains only traces of oil in wells Nos. A and 21, in all the other wells it is either dry or carries water. The first oil-sand, however, may in its turn follow immediately below the Yenangyoung stage, without the separating medium of clay (*a*) being present. Instances have been recorded in various wells; as No. A, No. 40, etc.

It is impossible to say whether in such instances as well No. 3 or No. 23 the "slate and sand" immediately below the Yenangyoung stage represents the first oil-sand; it is, however, highly probable, because, in the quoted instances, they have been discovered in the same position as the first sand in other wells.

(*c*) The first sand is usually followed by a bed of clay of varying thickness; it is very probable that the first two beds are occasionally absent, and that this bed follows immediately below the Yenangyoung stage; at least some of the boring registers cannot be interpreted in any other way.

(*d*) The second oil-sand follows, as a rule, below the above mentioned clay, but, as in the case of the above mentioned beds, there are instances which render it very probable that the upper strata are entirely absent, and that the second oil-sand follows immediately below the Yenangyoung stage. In thickness it varies a good deal and the record of No. 68 suggests the idea that in this instance the separating clay (*c*) is absent, the first and second sand thus forming a continuous series. Nowhere within the Kodoung area, except well No. 21, is oil found in this sand; it is usually dry, but sometimes yields a good deal of water.

It is possible that on the eastern side of Kodoung this bed is represented, as for instance in No. 3, by a series of thin alternating beds of clay and sandstone which are usually termed shales.

(*e*) Below this bed follows a remarkable stratum of darkish blue very tenacious clay, apparently without the slightest admixture of sand. This bed is a very constant one and has been found in all the wells where it caps the petroliferous sands. In thickness it varies very much and it is quite certain that in some instances like Nos. 11, 60, etc., it forms together with (*a*) and (*b*) clay, to the entire exclusion of the 1st and 2nd sand, an argillaceous layer of considerable thickness.

(*f*) The third oil-sand has been found in all wells, but to judge from the boring registers it must vary a good deal in thickness. It contains petroleum in a considerable quantity in all wells except Nos. 64 and 68 at Kodoung and Nos. I, V and VII. It is remarkable that in some instances the upper part of the third sand contained water which was followed by oil, for instance well No. 61; in others, like No. 36, the petroliferous layer was of small thickness, and was followed by a thick water bearing layer.

Wells No. A and No. 6 have such a remarkable boring record, that, provided they are correct, we are bound to suppose that by the intercalation of an argillaceous layer (*e′*) the part (*f′*) containing a considerable quantity of petroleum, has been separated from the 3rd oil sand. It is only in the above two instances that this feature has been noticed, and as these two wells belong to the earlier wells, when no special care was taken with regard to the boring register, it is quite possible that some error has crept in, in fact it is almost certain that the boring register of well No. 6 must be incorrect, because, as it stands, it hardly fits in with the adjoining wells.

(*g*) In all wells in which the drill passed through the third oil-sand, a bed of clay has been found immediately underneath it, which lithologically does not differ from any of the other clay beds.

(*h*) Below the above layer of clay occurs a thick stratum of arenaceous beds which forms the fourth oil-sand. It has been found in wells Nos. 40, 13, 51, 54 and 57. This sand does not always contain petroleum; in some instances like No. 54 it is water bearing at the top, dry in the middle and petroliferous at the base, it is apparently divided by some minor parting of clay in No. 51, while it is almost certain that it forms a continuous layer together with the third oil-sand in wells Nos. 59 and 60.

(*i*) There are only a few wells which have passed through the 4th sand, but there are proofs that it is followed by a comparatively thin bed of bluish clay.

Below this bed follows in well No. 54 a series of sandy layers one of which is petroliferous (*k*), separated by argillaceous partings. Whether these strata represent proper horizons, or whether we have to consider the series as a thick argillaceous bed subdivided by sandy layers, remains to be seen.

I have constructed the sections on plate XII, with reference to the above remarks about the sequence of the beds found in the petroliferous series. How far my views expressed in this way are correct remains to be seen. It is quite possible that, owing to the great similarity of the lithological character of the beds, errors have not been avoided in the correlation of some of the beds, but I believe that the main outlines of the sequence will be found to be correct.

As the wells are never situated in exactly straight lines, I have drawn across the area of the Kodoung field a series of transverse lines, connecting the greatest number of wells by a straight line, whilst others which did not exactly come within this line were included when they were not too far off. In this manner I obtained a series of cross sections which are shown on plate XII. A comparison of these transverse sections with each other, shows how hopeless it is to unravel the detailed structure of the Yenangyoung oil field. None of these cross sections quite correspond with each other. Of course a general sort of agreement may be made out, but the more I have studied and compared them, the more difficult it seemed to explain their unusual features.

The most conspicuous instance is shown in section V, between wells No. 19 and No. 11 and No. 10. In No. 19 immediately below the lowest bed of the Yenangyoung stage there is a bed of sand of 130 feet in thickness followed by the clay (*e*); in No. 11 immediately below the same bed a stratum of clay of 201 feet in thickness has been found, followed by a thin bed of sand containing petroleum below which follows clay (*g*); in No. 10, there is a bed of sand of 212 feet thickness immediately below the beds of the Yenangyoung stage separated from the oil-sand by a bed of 63 feet thickness of clay, noticed in the two other bore holes. Now it is quite evident that such a remarkable disappearance or thinning out of beds of nearly 200 feet in thickness within such a short distance would be rather anomalous, even if we admit that such rapid and sudden changes in the lithological character of the beds do take place within the same level.

In fact the problem of the discrepancy of the various sections puzzled me so much, that I considered it an almost hopeless task to obtain a clear idea about the structural features of the oil field; I almost felt inclined to assume that serious blunders must have been committed in recording the beds through which the borings were made. The study of Professor Orton's ingenious paper on the occurrence of petroleum in Ohio, suggested an explanation; he observed the remarkable fact that the successful wells were always on the domes while the dry wells were situated in sinks or depressions of the anticline.[1]

The idea suggested itself to classify the wells of the Kodoung

[1] Geological Survey of Ohio, vol. VI., 1888. Do. 3rd organization, vol. I., 1890. The Trenton limestone as a source of petroleum and inflammable gas in Ohio and Indiana, U. S. Geological Survey, 8th Annual Report.

tract (which, as we have seen, draw their oil nearly all from one and the same bed, the 3rd oil-sand) into three classes: poor wells below 500 gallons a day, better ones yielding between 500 and 1,500 gallons a day, and rich wells which yield more than 1,500 gallons a day. On entering these observations on the map, plate XV, not much seemed to be gained by this, rich and poor wells appeared to be distributed in a most erratic way, only the well known fact that in the Yenangyoung oil field a very rich and a very poor well may occur close together appeared to receive further support. Note, for instance, the case of wells No. 53 and No. 9, the former being a rich and the latter a poor well, although their horizontal distance is barely 180 feet. But when the wells of each single class were connected by lines, a most curious feature was almost at once noticed. The lines connecting each class did not run straight or in a slightly curved way, but they were arranged in a zig-zag course. The following will demonstrate this; wells Nos. 25, 27, 28, 26, 48, 55, 32, 35 are all rich wells, connecting these wells by an uninterrupted line, wells Nos. 25, 27, and 28 were situated on an almost straight bearing; at No. 28 the line took a sharp turn inwards, so to speak, and wells Nos. 28, 26 and 48 were again found to be situated on an almost straight line, the above named five wells were therefore situated on both sides of a very acute angle, at the apex of which was well No. 28; proceeding further from No. 48 towards Nos. 55, 32 and 35, these were again situated in an almost straight line, meeting the line 28, 26, 48 at a very acute angle, but running almost parallel to line 28, 27, 25.

So far this may be accidental only, but, luckily enough, a few more wells of the middle and poor class, proved almost to a certainty, that the explanation of these lines must be something more than a mere accident. On connecting the middle class wells Nos. 58, 30 and 31 by a line, it was found that they too were situated on a rather acute angle, well No. 30 at its apex and wells Nos. 31 and 58 on its sides, and that line 58, 30 was almost parallel to line 25, 27, 28, while line 30, 31, seemed to conform in its direction to that of wells 28, 26, 48.

How far the short line connecting wells Nos. 29, 62 and 67 conformed to these lines connecting the middle class wells was not quite clear, but another equally conspicuous instance suggested itself almost at once. On connecting the poor wells Nos. 14, 12, 15, it was found that these also were situated on an acute angle having its apex directed towards east. Wells Nos. 15 and 17 could not be connected by a straight line because the indifferent well No. 16 intervened which together with 17 and 15 is situated along an almost straight line. A line connecting the poor wells Nos. 17 and 15 must therefore pass to the west of well No. 16, and on following this clue another segment of a zig-zag line was exhibited, turning one point towards east, the other towards west. Now on crossing over to the eastern side of the petroliferous area, and connecting the poor wells Nos. 3, 8, 23 and 9, it was at once noticed, that wells Nos. 3, 8, 23 formed a very acute angle turning its apex, which is formed by well No. 8, towards west, while wells Nos. 8, 23, and 9 formed another acute angle, having 23 at its apex, but turned towards east. It is remarkable that the line 15, 12, 14 on the west side and line 8, 23, 9 on the east side are directed in the same way, that is to say, they have the apex turned towards east, and that inside the narrow band of land thus defined, there were the rich wells Nos. 7, 53, 43 and 13.

Another remarkable case was noted with regard to the indifferent wells Nos. 6, 10, and 4 and the poor well No. 5, No. A and No. 1; the first three are ranged in a line which forms an acute angle having its apex turned towards west, but inside this protruded the sharp angle A, 5, 1, in such a way that its apex, well No. 5, was almost directly between wells Nos. 6 and 4, being approximately not more than 200 feet from either.

It is needless to go into any further details, which can be easily ascertained by an inspection of the map; it is sufficient to say that the instances here mentioned rendered it almost beyond doubt that the wells are distributed along a zig-zag line, which follows a certain system.

The cue thus given has been followed up, and when not proved by the actual situation of a well, the direction of the lines was supposed to run parallel to another one already proved. In this way the map, plate XI, was constructed, and it is at once clear, that there must be a certain rule with regard to the situation of wells producing more oil than others. It will be seen that in thus connecting the wells of each class, by lines, each class is situated within a certain well defined area to the total exclusion of all the wells of other classes. We notice that the richest wells form a rather narrow belt in the centre, this is surrounded by a broader belt of indifferent wells, and the latter is again surrounded by a belt of wells yielding only a small quantity of oil.

Before proceeding any further I must at once explain that I do not by any means believe that the lines as laid down on this map represent actual boundary lines, the strip of rich wells may be a little broader than depicted, but it is clear that it cannot extend beyond the line connecting the indifferent wells, and the same of course applies to the latter with regard to the poor wells; they cannot possibly extend beyond this line. Though it may be quite possible that, with the advance of our knowledge of the structure of the oil field, the lines will be perhaps somewhat modified, the main features will probably remain.

The belts, it will be seen, run in a very curious zig-zag manner, and it is quite evident that whenever we find an indentation on the one side, it corresponds to a projection at the opposite one.

Another feature is also remarkable; it seems that the Kodoung petroliferous area is separated from the Twingon field by a band containing only a small quantity of oil, and that the tail end, so to speak, of the Twingon belt indents the Kodoung belt just at its north-eastern corner, as apparently indicated by the indifferent wells

Nos. 36 and 46 and the rich well No. 39. However, this feature cannot be followed up for the present, nor is it possible to say whether there exists a similar regularity in the distribution of the Twingon wells, because the latter do not draw their oil from one and the same level like the Kodoung wells. For the present we must therefore content ourselves with the study of the Kodoung tract.

It seems that it begins with an irregular elliptical area close to the Aung-ban ravine and continues in the shape of a comparatively narrow belt, the broadest extension of which between wells Nos. 52 and 67 does not exceed 2,500 feet in a straight line, while its minimum breadth is reduced to about 600 feet between wells Nos. 9 and 12, towards Beme, where it apparently again terminates in a similar irregular elliptical area. The total length of this belt will hardly exceed 5,000 feet, and it is quite evident that its general axis forms an angle with the general direction of the strike of the strata deviating towards west from the former or having a north-west bearing.

Within its two terminations the belt forms a series of zig-zags already mentioned, just as if it were folded by a pressure acting in the direction of the main axis.

Now the question obviously suggested itself. What relations do these curious zig-zag lines bear to the geological structure? If Orton's theory with regard to the distribution of oil in the strata is correct, *viz.*, that the richest wells are always situated on elevations, while sinks or sags generally prove to be dry,[1] then it is possible that the belt indicated by the rich wells marks the crest of a fold running in a zig-zag direction and that the indentations represent the sinks or sags? And further, if so, what structural conditions would answer to the first presumption? Supposing that the lines, as depicted on the map, represent a rough sort of contour lines, the only structure which could be imagined would be a series of roughly parallel folds which bifurcate, and are linked together in such a manner, that the branch of one fork opening in one direction also forms a branch of the next

[1] Orton, Geol. Surv. of Ohio, vol. I. p. 90.

fold, but opening in exactly the opposite direction. The following diagram will demonstrate this sort of structure.

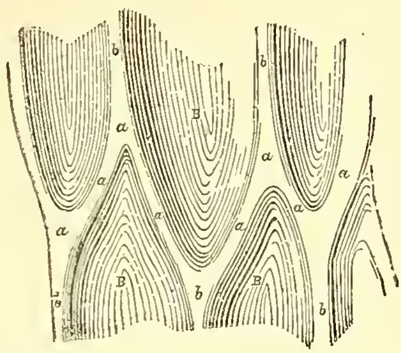


Fig. 8. Diagram showing arrangement of the intersecting folds in the Kodoung petroliferous tract.

The line marked (*a*) would represent a zig-zag ridge, running exactly as the oil belt does, sending off lateral branches (*b*) separated by hollows B.

Let us for the moment disregard the question of the origin of such a peculiar structure, which will be dealt with later on and, assuming it to exist, I shall have to endeavour to show that this structure originated at the time of deposit of the petroliferous strata, which view I trust I shall be able to prove.

As regards the physical conditions of the folds it is by no means necessary that the crest of the central ridge should retain the same level throughout, in fact it is most probable that it would not, and that its height would vary; at the same time it is by no means necessary that the lateral branches (*b*) should all be of the same length, they will probably vary very much, and it is also very probable that they eventually flattened out and entirely disappeared.

Now let us consider the nature of the deposits formed under the above conditions; it is very probable that these may have been entirely different on both sides, on one side sandy beds were deposited, while on the other argillaceous beds were formed; at the same time owing to the oscillation of the central crest a communication may have existed between B and B′ while there was none between B′ and B″, beds in B and B′ may therefore exhibit a certain similarity, while there is a vast difference between the physical nature of the beds in B′ and B″. It is also very probable, that towards the heads of the basins, where they were sufficiently separated, the sequence of the series varied considerably in adjoining basins, while further towards the end where the separating ridge (*b*) becomes lower the beds join and assume a more uniform character.

It will be seen that the above theory will allow for an enormous variety of details in the deposit, which can be multiplied to any degree if we take into account the contemporaneous erosion, which has been repeatedly proved.

Now I must confess, that when looked at from the points of view of this theory the sections of the deep boring appeared in quite a new light. Certain anomalies, as for instance in section V, the rapid change of a bed of clay of 201 feet thickness in No. 11, into a sandy layer of 212 feet thickness in No. 10, were easily explained by the above theory; No. 11 is situated at one and No. 10 at the other side of the central basin, hence the difference of the physical nature of the sediments within so short a compass.

We are, however, in a position to test the correctness of the above theory by the comparison of the boring registers, but then we must at once dispose with the orthodox method of simple sections across the strike, and we will have to arrange the sections in such a way as required by the above theory, that is to say, quite irrespective of the present direction of dip and strike.

It is one postulate of the above theory that the rich wells ought to be situated along the direction of the central ridge and not on its lateral off-shoots, occupying generally the highest points. We should therefore observe a rise of the petroliferous beds, from the wells of lower production towards those of the higher.

Another postulate would be that within the area supposed to be occupied by the basins we should observe a slope of the beds towards the centre of such basins.

To prove these postulates absolutely a much larger number of borings would be required ; as may be seen from the map, at most places the lines are purely conjectural, and frequently the crucial points are wanting in order to complete a given section. However, there is still sufficient information contained in the boring registers to strongly support my theory.

A most favourable part is the northern end of the oil tract, although there are unfortunately some four or five wells the boring records of which are missing although they would be of the utmost importance.

As shown on the map the rich well No. 47 is surrounded on all sides by a series of indifferent wells Nos. 11, 19, 20, 21, 6 and 10 ; and these again are surrounded by an irregular circle of poor wells Nos. 66, 64, 2, A, 5. The theory therefore requires that the petroliferous bed of No. 47 should represent the highest point, and that from thence it should slope in every direction, excepting of course that which forms the continuation of the central ridge.

These borings are numerous enough to allow of three sections being constructed; one in south-south-east and north-north-west direction, in fact, it is almost along a north to south line connecting wells Nos. 11, 47, 21. The second in an east and west direction, connecting wells Nos. 64(*a*) 20, 47, 10, and thence proceeding further towards wells Nos. 8, 7 and 9. The third in a south-west to north-eastern direction, connecting wells Nos. 19, 47, 6, A, and 36.

(*a*) Section XX, pl. XIII, wells Nos. 11, 47, 21.

The section in well No. 11 affords a very curious instance of a large development of argillaceous beds ; after 75 feet of strata belonging to the Yenangyoung stage, there follow 221 feet of argillaceous beds, below which the petroliferous sand, to the thickness of 97 feet, was found resting on water bearing sand. The top of the oil-sand was therefore 170 feet above sea level.

In well No. 47 the section differs already considerably ; instead of a compact bed of clay, as in No. 11, the argillaceous beds are separated by a sandy bed of 25 feet thickness containing water at

220 feet above sea level, and on the top of the clayey beds rests a bed of 50 feet of "blue sand" which must be separated from the overlying beds of the Yenangyoung stage. The petroliferous sand to the extent of 79 feet thickness was found at 274 feet from its surface, and is found 200 feet above sea level.

In No. 21, we observe a further change, the sandy bed immediately below the Yenangyoung stage, 80 feet thick, contains a small quantity of oil and unquestionably represents the top sand of No. 47 and overlays an argillaceous bed of 130 feet thickness which exhibits the same feature towards its base as seen in No. 47, that is to say, it becomes sandy, thus probably representing a series of alternating argillaceous and arenaceous beds. The petroliferous sand to the extent of 42 feet rests on petroliferous sand and was met at the depth of 290 feet from the surface and its top was 180 feet above sea level.

The top of the petroliferous sand was therefore found in—

	No. 11.	No. 47.	No. 21.	
at	170	200	180	feet above sea-level.

These figures prove that there must exist a rise of its top from No. 11 towards No. 47 and a fall from No. 47 towards No. 21.

(*b*) Section XIX, pl. XIII, wells 64(*a*), 20, 47, 10.

The series begins in No. 64(*a*), below the Yenangyoung stage with a bed of "blue" sand of 30 feet thickness, followed by an argillaceous bed below which 45 feet of "water sand" were found followed by 100 feet of clay. The petroliferous sand was struck at 280 feet from the surface or 180 feet above sea level, it is very poor in quality and rests on water sand.

In No. 20 the section is not as complete as it might be. Below 62 feet of beds belonging to the Yenangyoung series, 86 feet of "fine soft grey sand with beds of shale" were found; it is not impossible that the series was sand at the top and clay at the bottom immediately above the thin layer of water sand. The petroliferous sand capped by a bed of clay, was found at 268 feet from the surface or 200 feet above sea level.

Well No. 47 has already been discussed, its section above the petroliferous sand bears the strongest resemblance to that of the former two wells only that the argillaceous beds predominate, while in the former the arenaceous beds are thicker. A remarkable change takes place in the sequence of the beds passing from No. 47 to No. 10, a distance of 460 feet in a straight line. Below the beds of the Yenangyoung series, a series of 162 feet follows, described as "soft grey sand and slate," which rest on 20 feet of inferior oil-sand. It is difficult to find out whether argillaceous beds intervened; it may be probable, inasmuch as the term "slate" seems to indicate this, but it seems to be almost certain that they were of no importance. I interpret this sequence of strata as the series of thin beds of clay alternating with sand, which is exposed in the Aungban-yo, well developed on the eastern side of the petroliferous tract. The oil-sand was met with at 305 feet from the surface or 147 feet above sea level.

Dwelling for a moment on the results of these four wells we note that the top of the petroliferous sand was found in—

	No. 64 (*a*)	20	47	10
at	170	200	200	147 feet above sea level.

It rises therefore from No. 64 (*a*) in the direction of 20, keeps on the same level between 20 and 47 and falls rapidly towards 10.

(*c*) Section XVIII, pl. XIII, wells Nos. 19, 47, 6, A, 36.

Well No. 19 represents a remarkable set of beds; immediately below the Yenangyoung series follows a rather thick series of sandy strata with probably argillaceous parting somewhere near the base, although the register is inaccurate in this respect, stating only that soft "grey sand and clay" were found between 95 and 210 feet from the surface, but whatever the thickness of this argillaceous bed may be it is clear that it cannot be great, and that No. 19 is therefore in accord with Nos. 66, 64, 20, 21 as shown by the preponderance of the sand beds. The top of the petroliferous sand was found at 319 feet from the surface or at 138 feet above sea level. Well No. 47 has already been discussed.

The section of No. 6 is very incomplete, all that is known is that comparatively close to each other two oil-sands were found, one at 225 feet, the other at 310 feet from the surface, which it is extremely difficult to correlate with those found in different wells. The boring records of Nos. A, 6 and 10 seem to indicate the existence of an oil-sand above the chief oil producing sand which has not been found in any of the other wells. If we suppose the upper sand to be the continuation of the 3rd sand in No. 47, there is a rise in its level from No. 47 towards No. 6; if the lower, then there is a fall.

The question becomes still more complicated if we proceed towards A where there are four consecutive sands, the 1st, 3rd and 4th in the sequence being petroliferous, the 2nd dry, and compare these with the adjoining No. 36 where there is only one sandy bed altogether.

If my interpretation is correct and the last arenaceous bed in wells Nos. 6, A and 36, the top of which was found at 160 feet above sea level in No. 6, at 200 feet in No. A, and at 220 feet in No. 36 represents the 3rd oil-sand, then its level falls from 47 towards 6 and rises from there towards A. To me this seems most probable, as it is unquestionably proved by the remarkable run of the line connecting the poor wells Nos. 2, A, 6, 1, 41, 40, 3, 8, north of which the two indifferent wells Nos. 46 and 36, and the rich well No. 38, are situated, that a new element in the series stretches from Twingon towards Kodoung, the east end of which is represented by the wells Nos. 36, 38 and 48. This question unfortunately cannot be gone into for the present, not only because the boring registers of four wells Nos. 1, 2, 4, 5 are missing, but what is more important, because nothing is known at present about the deeper structural features of the Twingon tract. To me the new feature seems sufficiently represented by the petroliferous sand found at 230 feet above sea level in No. 6, 240 feet in No. A, and 250 feet in No. 10. On the other hand, it must be mentioned that the boring register of No. 46 which should fall into this region, exhibits nothing unusual. However, the question must remain open for the present until the deep wells drilled in the Twingon tract shall give further indications as to the way these indications ought to be followed up.

We must therefore content ourselves to assume that it has been unquestionably proved by two sections drawn at almost right angles across the northern end of the Kodoung oil tract, that the top of the 3rd oil-sand rises towards the centre, or, in other words, from the poor and indifferent wells to the rich well No. 47. In a third direction this has been almost proved to a certainty. The result of the above argument is that the northern end of the Kodoung petroliferous tract must form an irregularly shaped dome probably slightly elongated in north-east to south-west direction, the centre of which is occupied by a rich well and the outskirts by wells gradually decreasing in productiveness. So far the object of proving the series of intersecting folds has not been much advanced, but a section along the western side of the petroliferous tract ought to show whether there exist such undulations as supposed, and whether, this is the chief point, these undulations correspond to the ridges and bases of the intersecting folds.

The section connects wells Nos. 66, 19, 11, 18, 22, 12, 43, 58, 27 and 26 and in order to avoid unnecessary length of description it will be best to enter at once into the discussion of the upper level of the 3rd oil-sand, and to deal with the upper beds conjointly afterwards. Beginning at the northern end the 3rd oil-sand has been found at the following levels:—

No. 66	140 feet above sea level.
No. 19	140 ,, ,, ,, ,,
No. 11	170 ,, ,, ,, ,,
No. 18	170 ,, ,, ,, ,,
No. 22	195 ,, ,, ,, ,,
No. 12	160 ,, ,, ,, ,,
No. 43	217 ,, ,, ,, ,,
No. 25	230 ,, ,, ,, ,,
No. 58	187 ,, ,, ,, ,,
No. 27	198 ,, ,, ,, ,,
No. 26	210 ,, ,, ,, ,,

The line rises therefore from the poor well No. 66, towards the indifferent well No. 11, remains steady up to the similar well No. 18, rises again to the rich well No. 22, falls quickly to the poor well No. 12, rises from these steeply to the rich well No. 43 (13 of course included) falls towards the indifferent well No. 58, here I may add that if the direction from 58 to the rich well No. 25 which runs at about a right angle to the direction of the main section is followed up it will be seen that there is also a considerable rise ;[1] from 58 the line rises again towards 27 and 26, beyond which this section cannot be continued, neither No. 55 or 48 bringing in any new feature, while No. 56 is most probably already on the eastern side of the belt. If we consult the section we notice that, excepting slight local differences in the thickness, the undulations of the 3rd oil-sand are followed by clay (*e*) but above the latter bed we notice some very curious differences which will presently be discussed.

These facts I believe prove sufficiently that the top of the 3rd oil-sand describes a series of undulations along a line which is almost parallel to the present strike of the strata. I will now attempt to show the connection which may exist between this undulating line representing a vertical, and the zig-zag lines probably representing horizontal contour lines. The theory of the intersecting folds as applied to the Yenangyoung oil field requires the presence of a trough or basin on the western side of the tract between wells Nos. 47 and 22. Unfortunately a connecting link is missing here, that is to say, a well between Nos. 19 and 18, and it may be questioned whether it is admissible to place well No. 17 in this place. However it is quite evident that a ridge does exist extending from No. 47 in south-westerly direction, which is crossed by a line which connects Nos. 66 and 19, indicated by a rise. The presence of the sag or trough between 18 and 19 is not quite proved, but it seems to be indicated by the rise from Nos. 19 and 18 towards No. 11 and further on towards No. 47.

[1] For obvious reasons well No. 25 has not been included in the diagrammatic section.

Further, the theory requires the existence of a ridge between Nos. 18 and 12, on the top of which the rich well No. 22 is situated. There could hardly be anything more conspicuously expressed than is the presence of this ridge by the run of the top of the 3rd oil-sand; note the rise from 18 towards 22 and the quick drop from 22 towards 12.

Passing along this subterraneous ridge in a westerly direction we come to well No. 16, where the top of the 3rd oil-sand has been found at 180 feet above the sea level, thus indicating a fall in the height of the ridge.

Another ridge must be assumed between Nos. 12 and 58; nothing seems better demonstrated than this by the section exposed by drilling wells. Again we observe that the richest wells are situated on the highest point, following the direction of the ridge towards west, we observe that in well No. 14 the top of the 3rd oil-sand is only 130 feet above sea level.

A sag is supposed to exist between Nos. 43 and 27 as shown by the rise which exists between wells Nos, 58 and 25.

The ridge on which wells Nos. 27, 28, 26, 48 are situated is proved to a tolerable certainty, but not so the sag following immediately south of it.

It exists most probably because from well No. 26, where the top of the oil-sand is met with at 210 feet above sea level, there is a decided fall towards the indifferent well No. 31 where it was found at 200 feet above sea level. Following up the direction of this ridge in a westerly direction towards wells Nos. 29 and 28, we may observe again the usual fall in the level of the top of the 3rd oil-sand.

In No. 28 it was found at 170 feet above sea level, whilst at No. 29 it was only 155 feet. It appears, therefore, that the richest wells have been found to be situated at such places where the petroliferous sand rises highest to the surface, and the poorer wells are found in places towards which the 3rd oil-sand slopes from richer localities.

When examining the younger strata in the boring registers we may observe at once a very curious feature. Very thick argillaceous beds are found in all the wells which are situated inside the areas indicated as depressions. This thick argillaceous bed was first noticed in well No. 11, extending from there towards No. 47 where it is divided by a sandy layer. From No. 11 the argillaceous bed passes between Nos. 19 and 18 and to the north of No. 17. Its horizontal extension must have been very limited in this region. From north of No. 17 it must sweep around but outside Nos. 16 and 15, and it is seen again in the same thickness; its horizontal extension must be still more limited in this part.

From there it passes outside No. 14, reaches up as far as No. 58, although not in the same thickness as previously noticed, and must pass west of No. 62, but east of No. 64, and passing No. 67 which is probably close to its western limit. It appears in its former strength again in No. 30, and reached up in the depression as far as No. 48.

Slight traces are only noticed at No. 55, not at Nos. 32 and 35, but in well No. 39 it again assumes the former thickness of over 200 feet divided only by a thin layer of sand.

Its further extension cannot be accurately defined; at No. 60 it appears as a continuous layer of 260 feet in thickness, extends to the south towards No. 63, where it reaches 295 feet in thickness, from thence it sweeps round the southern end of the oil tract, being found in No. V with 295 feet, in No. VI with 356 feet, and in No. VII with 290 feet; near this point it is lost and it certainly does not appear on the eastern side, but it unquestionably extends as far down as No. I where it has been met with inconsiderable strength.

This argillaceous bed is followed by a sandy stratum, which generally increases in thickness when the argillaceous bed decreases, and *vice versâ*. It deserves mention, that this second sand which begins north of the oil tract, describes a similar series of folds to the third sand, although it does not contain oil anywhere.

Section X.—Before turning to the eastern side I wish to draw attention to section X as this traverses the central ridge. This section hardly requires any explanation. From No. 14, where the top of the No. 3 oil-sand has been found at 135 feet above sea level, it gradually rises towards No. 25 where it was found at 225 feet; from there it falls slightly towards the inferior well No. 37, more so towards No. 42, where it reaches the level of 170 feet above sea, and now, as may be supposed according to the theory, it rises again towards the inferior well No. 50, where its level is 185 feet above the sea. This section affords, therefore, a very good idea of the slope on either side of the central ridge on which the rich wells are situated.

The eastern side of the petroliferous tract.—In the same way as the longitudinal sections were constructed on the western side of the tract, a similar one might be constructed on the eastern side, but unfortunately the wells are not so numerous there; and the few which do exist are separated by such long intervals, that it is impossible to construct such a complete section on the western side. I may, however, be allowed to quote a few instances; the rise of the surface of the 4th oil-sand from the poor well No. 52 towards the inferior well No. 50 has already been mentioned; the same applies to the tract from well No. 49 towards No. 53, or No. 40 towards No. 38.

It would be useless to go further into details; I think the above has conclusively proved that, independently of the general structural features expressed in the dome like shape of the Yenangyoung oil field, there exists a series of folds, transverse to the direction of the axis of the anticline, which must have existed previous to the formation of the latter. It remains, therefore, only to explain the origin of these folds.

d.—*The original sedimentation of the petroliferous beds.*

In the foregoing section I have shown that the Yenangyoung oil field exhibits a very complicated structure, due to two causes, *viz.*:—

1. A transverse action, resulting in the creation of the anticlinal and longitudinal arch.
2. A longitudinal action, resulting in the creation of the intersecting folds.

I have further shown that the intersecting folds must have existed before the anticlinal arch was raised. The question to be answered is, therefore, by what hypothesis can we explain the origin of the folds? I think the theory to be promulgated will explain all the curious features, but before giving it in detail, it will be necessary to recapitulate a few facts. We may take it as proven that the petroliferous beds of the Yenangyoung oil field at least, were deposited near the mouths of a large river, or perhaps in a lagoon, communicating with such a river. The proofs for this view are:—

(*a*) The fauna discovered is the petroliferous beds.
(*b*) The bedding of the strata.

With regard to the first point, a mixture of terrestrial animals, mostly in rolled fragments, and marine fossils has been found in the petroliferous beds. A mixed fauna of this type cannot possibly have been deposited far from the coast, even if we admit that the floating carcases of terrestrial animals have been carried away by the tides, for some distance from the shore. With regard to the second point, I have demonstrated that the stratification of the petroliferous beds exhibits such curious features, that we feel bound to suppose that they were deposited in a water subject to periodical and sudden rises like those of tropical streams of the present day. I have above pointed out that it is only the action of a quickly rising current by which we can explain the local erosion and the subsequent deposition of beds, hereby creating local unconformities.

I think the above two views do not require any further proofs and, if accepted, the ground is clear for the theory of the origin of the folds.

Such a phenomenon is in fact represented to some degree by a mud stream running down the slopes of a mud volcano, and it was in fact this observation which first suggested the theory. When the liquid mud has reached the less inclined basis of the mud volcano its speed slackens, until its front has come to a standstill, while the upper masses are still in a downward movement. The result is that those parts of the stream which were first arrested bulge out and a series of wrinkles, running transversely to the direction of the mud stream, are formed on its surface, which sometimes join each other, or in other instances burst, while some liquid mud flows out and fills up the unevenness between the wrinkles. I have described this above (page 47), but it will be seen that we have only to assume that this same process has been taking place on a larger scale to find the explanation for the intersecting folds.

Let us suppose that the ground on which the petroliferous beds were originally deposited formed a plane slightly inclined towards the open sea, an assumption which is quite compatible with the view of their deltaic origin, and let us further suppose that this plane eventually became horizontal. On this inclined plane a thick stratum of sand was deposited, followed by an argillaceous bed, and on this another sandy layer until the weight of these masses which were permeated by water and in a state of unstable equilibrium set them in motion. The whole mass would then slide down on the inclined plane until it was arrested by the change of the gradient.

What would be the result of such a process? Certainly something very similar to what is exhibited by the mud stream. The strata would bulge out, they would form a series of folds, transverse in direction to that of the movement of the strata, and they would be intersected by numerous cracks and veins filled with mud, which would also spread on the surface, perhaps filling out the interstices between two folds. The single beds thus set in motion and arrested again, would certainly exhibit a great inequality of thickness as well as their surface would be very uneven, unless they are filled out by "eruptive" mud.

Now let us analyse how this theory agrees with the observed facts.

I have above pointed out (page 124) that the strange arrangement of the drilled wells suggested a peculiar structure. I have proved to some extent at least, that this peculiar arrangement is unquestionably due to the presence of some transverse folds in the upper Prome stage, which apparently do not reach to the surface, but which must have been formed previous to the deposit of the Yenangyoung stage. These intersecting folds represent the wrinkles on the surface of the mud stream or the folds which must have been produced by the sliding of the masses according to the above theory. Could we ascertain that they were slightly curved, the proof would be conclusive, but the data available for the present are too scanty to prove this. As it is we must rest satisfied that there exist such folds as required by the theory, and we have now to investigate the question whether there is any other additional evidence which supports the theory. Now what stronger proof can there be than the presence of veins filled with eruptive mud and the beds of eruptive mud injected between the other strata as described on page 83. In fact the presence of the mud veins becomes only intelligible in view of the above theory, and their more frequent occurrence in the southern part of the field tends to indicate the region which was under the greatest pressure which therefore was nearest to the termination of the downward movement.

It is further quite obvious that when a series of beds is simultaneously moving, and eventually arrested, the single beds must become in some parts compressed and in others stretched or thinned. In other words an individual bed must exhibit a great variation of thickness within a limited horizontal extent. I think that the sections of the deep borings have given ample proof on this point. Although we might explain the reduction of thickness by local erosion, the increased thickness can only be explained by compression.

We may now even go a step further and suppose that while the above mentioned process was going on, younger beds were deposited on the top of those in motion, a supposition which would result in the most complicated structure of the series.

It seems almost quite certain that the sliding process was terminated before the deposit of the lower beds of the Yenangyoung stage began, because there is no indication of the intersecting folds in these beds, although it seems certain that they were deposited on very uneven ground.

The theory may be accepted or not, but I contend that it explains a number of very peculiar stratigraphical features in an unstrained manner, for which it would be difficult to account in any other way. I wish however to say that I do not want to generalize; the folds have hitherto been only observed within the limits of the Yenangyoung oilfield, but it is quite probable that they may also occur elsewhere.

D.—General conclusions, and future prospects of the Yenangyoung oilfield.

The numerous deep borings have shed so much light on the extension of the Yenangyoung oilfield, that we are now in a position to state with comparative accuracy that the Yenangyoung oilfield is of very limited extension, hardly exceeding 350 acres in superficial area.

With regard to the vertical extension we are in a less definite position; we know that up to a depth of nearly a thousand feet a series of sandy beds occur which may be petroliferous or not. Whether the lower boundary of the oil bearing series has been reached or not is impossible to say at present. Only an actual test will decide this question, but for the present it seems to be proved beyond doubt that it is the third oil sand, met with at depths averaging from 200 to 250 feet from the surface up to about 300 to 350 feet, which chiefly supplies the present yield. As already stated, it is impossible to say whether richer sands may exist at greater depths or not, and we have therefore only to deal with those parts of the oil bearing series of which we know something definite. We know therefore as well as has been ascertained for the present, that up to a depth of about 900 to 1,000 feet only one bed of sandstone has been found capable of producing oil in quantities. It is from this bed that the bulk of the pit wells and nearly all the drilled wells draw their oil. It is safe to say that about 75 per cent. of the total yield is derived from the third oil sand and if this bed shows signs of exhaustion, the end of the Yenangyoung oil production will not be far off. We will have therefore chiefly to investigate whether such signs are noticeable or not. For this purpose it will be convenient to divide the oilfield into two parts according to the method by which it is exploited, because, as we will presently see, other factors besides exhaustion tend to shorten the life of at least a certain portion of the oilfield. The two parts are the Twingon and Beme reserve forming the northerly and southerly part of the oilfield chiefly exploited by the natives, and Kodoung, the central part exploited by deep wells.

A.—The native reserves (Twingon and Beme tracts). With the exception of the drilled wells inside the lots, which are the property of the Government, these two tracts are at present exclusively worked by pit wells. As stated in the economic section, the method of extracting oil by pit wells is restricted by the depth to which the labourer digging the well can safely go without resorting to artificial ventilation. This limit can be fixed at 320 feet depth at most. When, therefore, all wells which can possibly be constructed within the boundaries of the native reserves have reached that depth the production must come to a standstill unless the method of drilling is resorted to. A decrease in the production of the pit wells need therefore, by no means, indicate the near exhaustion of the area exploited by these wells, it only proves that the beds capable of being reached by pit wells, that is to say, the first, second and part of the third oil sand are exhausted. The deeper part of the latter may still contain a considerable quantity of oil, inaccessible, however, by the native method of exploitation.

We will have therefore to answer the question, does the depth of the present productive wells in any way reach the above limit? As will be seen later on there are at present 519 productive wells; out of which there are about 107 which have been constructed since the close of 1893, and there remain therefore 412 wells, or approximately 80 per cent. which were in existence previous to 1893;

out of these 412 wells I selected 328 wells of which it could be proved that they had been permanently productive since the beginning of 1891 or during the last four years, all the others were disregarded. These 328 wells, representing 65 per cent. of the total number, supply 64 per cent. of the total production and are therefore of the greatest importance in answering this inquiry. It is obvious that, if these wells begin to show signs of exhaustion, the production must naturally decline, unless other means are devised to keep it up.

These 328 wells, all of which have been identified, had an aggregate depth of 67,340 feet in 1891; that is to say, the average depth of each well amounted to 205 feet.

In 1893 these same wells had an aggregate depth of 73,471 feet, or the average depth of each well had reached 224 feet from the surface.

In 1895 the depth of these wells had increased to an aggregate of 74,952 feet or each well averaged 228 feet in depth.

These figures will be more impressive if we express them in percentages of the possible depth, estimated at 320 feet; in this case the average depth of each well amounted to—

in 1891	. . . . . .	64 per cent. of possible depth.
„ 1893	. . . . . .	70 „ „ „
„ 1895	. . . . . .	71 „ „ „

The above figures unmistakably prove therefore that 65 per cent. of the productive pit wells have reached at the beginning of 1895 71 per cent. of their greatest possible depth. In other words, 65 per cent. of the existing productive wells, supplying 64 per cent. of the total yield of oil, have reached such a depth, that they approach very closely their maximum depth, which they would reach within the next seven years certainly, unless the difficulties in reaching that depth become so great that they had to be previously abandoned.

From this point of view the outlook is a very serious one, and the more so because it is based on undeniable facts.

It may, however, be counteracted in two ways, one of which has already been referred to: these are—

(*a*) by increasing the number of productive wells,
(*b*) by adopting the system of deep borings.

As regards the first remedy it has already been largely drawn upon; 107 new wells are oil producing, 151 wells under construction are expected to produce oil in a short time, and 281 places have been selected on which to construct new wells. So far so good, but the native reserves as well as the Yenangyoung oilfield cover only limited areas; the native reserves have been demarcated in such a way as to allow room for a total of 2,250 pit wells (see page 233). Out of these 2,250 well sites, 1,190 are already occupied, and there remains therefore only space for 1,060 new wells,—theoretically at least. Whether it will be possible to locate these 1,060 wells among the already crowded wells remains to be seen; it is my opinion that this is very doubtful, and that the nature of the land hardly allows for half this number. However that may be, it is certain that the decline of production cannot be counteracted by an unlimited increase of the productive wells. It may be that this remedy will answer, say, for the next five years, but the day must surely come when it will fail, and when the wells will all have reached their greatest limit of depth, and that day will mean the end of the native oil industry, at least as regards the system of exploitation by pit wells. As far as my experience goes this day cannot be very far off, and if the facts are correct it will occur within the next ten years, perhaps even within a shorter period. As already stated this by no means proves that the native reserves are entirely exhausted, it proves only that the upper parts, accessible to pit wells, are exhausted, and that in order to exploit the deeper parts, another system of exploitation will have to be adopted. That there is only one way, that of deep drilling, need hardly be explained, but it may be doubted whether the natives are capable of availing themselves of this method. As far as my experience goes I seriously doubt it; none of the present well owners commands the capital necessary to cover the first outlay, nor is it probable that their suspicious character will allow them to combine and raise the necessary capital among themselves. I believe that they will eventually sell the wells which are useless to them for a trifle to those who by their superior methods may give a new life to the oilfield, provided, of course, the strata have not been exhausted, a probability which we will have to examine now.

In a previous paper[1] I wrote the following with regard to the pit wells: "As regards the average daily production per well we notice a considerable decrease in the total average since 1888 from 56·1 viss to 47·65 viss. Of the different classes the highest decline will be noticed in the IIIrd class, if we except the Vth class as containing too small a number of wells to give a reliable result. We therefore see that in that class of wells, which contributes the largest share to the production, a very considerable decrease of the average production, amounting to 14·6 per cent. of the production in 1888 took place. In other words that bed of the oil bearing strata which hitherto supplied six-tenths of the total production shows unmistakable signs of exhaustion." I emphasized this view repeatedly in the paper above quoted, and I am now in the position to check it. I select again the 328 wells, which have been in continuous working order since the beginning of 1891, omitting all those which have been added in the meantime. The aggregate daily production of these wells amounted to—

in 1891	16,935 viss.
„ 1893	22,192 „
„ 1895	19,200 „

that is to say, the average daily production of a single well was—

in 1891	51·6 viss.
„ 1893	67·7 „
„ 1895	58·5 „

[1] Report on the Petroleum Industry in Upper Burma. Rangoon, 1891, page 33.

I think these figures show sufficiently that the bed from which now 64 per cent. of the total production is drawn shows unquestionable signs of exhaustion; we notice therefore the same phenomenon as in 1891 when a decrease in the average yield was observed as against 1888. This decrease was at once counteracted by an energetic deepening of the wells which was in fact carried out to such an extent that each well was increased 19 feet in depth on the average. The result of this operation proved a success and the average production per well rose to the extent of 16·1 viss per day.

Between 1893 and 1895 these same wells were again deepened to the extent of 4 feet on the average per well. The operation did not, however, prove a success, because the production instead of rising declined to the extent of 9·2 viss per well per day, so that at the beginning of 1895 each of the 328 productive wells which represent 65 per cent. of the total number, and supply 64 per cent of the total production, produces only about 7 viss more than in 1891, although each well has been deepened to the average extent of 23 feet, since that year. Were therefore the production of the native wells not supported by 107 recently constructed wells, exploiting a part of the reserve hitherto not worked, instead of an increase, the production would show a distinct decrease as compared with 1893. In fact we are in a position to estimate that decline with some precision. Under the above conditions the decline of the 328 wells, as compared with 1893, would amount to 90,528 viss per mensem.

This however does not represent the total amount of decrease, there are 84 more productive wells[1] which have not been included among the 328 wells because their history shows that they have not been productive for the whole time since the beginning of 1891. As it is safe to suppose that these wells have been influenced by the

[1] Out of these 84 wells, 78 existed previously, while six were added during 1895, these being dug in the older part of the field have not been included among the other wells dug in the new parts, and it is supposed that their production was equally affected with the general exhaustion as the others.

decline noticed in the 328 wells, they would show a loss of 23,184 viss per mensem ; the total decrease of the production originating from the exhaustion of the petroliferous sand would therefore amount to 113,712 viss per mensem, or everything remaining the same the average monthly production in 1895 would have amounted to 629,446 viss, instead of 788,297 viss.

Instead of the production having fallen off, it has actually risen to the extent of 45,139 viss per mensem, as against the preceding year, while the productive wells have increased to the number of 107 as compared with 1893. The question may therefore be raised whether the production of these 107 new wells is sufficient to balance the estimated loss in the production of the 406 older wells and to account for the increase ; in order to answer this satisfactorily I have made the most careful enquiries about the production of these 107 new wells which amounted to 6,423 viss per day or 192,690 viss per mensem, or 33,837 viss per mensem above the required amount. We see therefore that not only do the new wells fulfil the required conditions, but they actually supply somewhat more than required, from which we may naturally infer that the aggregate production of the 412 old wells is a little smaller than has been calculated.

We may therefore consider it as proved that notwithstanding the increased depths of the wells, the production has declined, a phenomenon which may be considered as the surest indication of the exhaustion of the bed exploited by these wells.

I think that the above conclusion bears out my statements made in 1891, namely, that the bed of petroliferous sand which supplies six-tenths of the production begins to show signs of exhaustion. I purposely refrained from taking the state of wells in 1888 into consideration, because I am unable to identify the individual wells of that year with those considered above, but I firmly believe that they would prove the same condition.

It is quite possible that when boring deeper fresh parts of the third oil bearing sand will be opened out, but as I have pointed out above, the difficulties in getting beyond a certain depth prove unsurmountable to the native well digger, and the only way to extract the petroleum from the deeper strata would be the construction of drilled wells. It must, however, not be entirely forgotten that even those may prove futile, and that the third sand is already nearly exhausted within the boundaries of the reserves. This can however be only proved by an actual experiment.

There are, I may state, some facts which in a measure tend to support such a view, but into which it is needless to enter here.

To sum up shortly I believe the prospects of the native reserves are as follows :—

1. It is very probable that within the next five years digging operations will be most energetically carried out, and the number of the productive wells will increase.

2. The production is likely to increase still more, although to no considerable extent, but in no distant future it will rapidly fall off, partly because the pit wells have reached their greatest depth, partly on account of exhaustion of the petroliferous sands.

3. The production of the Beme tract which has shown marked signs of decline as late as 1891 continues to fall off.

4. The Twingon reserve has probably already passed the zenith of its existence, and its production will probably fall off within a few years.

5. Although deep borings might delay the final end for some time, by exploiting deeper strata, it remains to be seen whether they will be successful or not. The chances are however more in favour of failure.

I claim that my views regarding the prosperity of the oil bearing tract have been borne out by facts: In 1888 I wrote ;[1]

"The Twingoung oil field is at present at the zenith of its production, but still a small increase may be expected for the next few

[1] Report on the Oil fields of Twingoung and Beme, Rangoon, 1889, and Records of the Geological Survey of India, 1889, vol. XXII.

years. The Beme wells have nearly extracted the oil existing in the oil bearing sandstone and a decrease of production is to be expected."

B. The area exploited by the drilled wells (Kodoung).

No such difficulties as regards limited depth obstruct the drilled wells. If it were known certainly that an exceedingly rich oil sand were to be found at 2,000 feet, every well would at once be brought down to that depth. The future of this area is therefore simply dependent upon the quantity of oil stored in the different sands and the annual off take. Although the latter is well known it would be exceedingly rash to form an opinion about the former. We know that the Kodoung wells draw their supply chiefly from the third oil sand, but how long this will last is difficult, if not impossible, to say.

The question will be the more difficult to answer if we assume a general flow of oil towards the wells ; in this case the production will of course last longer than if only dependent on the oil within the boundaries of Kodoung, because the oil is attracted from the more distant places towards the deep wells.

However there will probably come a day when the third oil sand will be entirely dry ; in this case the wells will have to exploit the deeper sands. Whether those are capable of supporting the present large production is impossible to say, so far as can be judged from the few observations the chances are not favourable, however I do not wish, considering the inconstancy of the strata, to attach too much weight to those few instances in which we have become acquainted with the sequence of the beds below the third oil sand.

Taken as a whole the Yenangyoung oilfield has by no means answered the expectations which were entertained about it. It is limited in area, and we may almost certainly assume that its production will always be a modest one. It is almost certain that its production will rise somewhat during the next few years, but it is most probable that then a decline will set in. My opinion is that this decline will take place within a limit of ten years or even earlier.

In conclusion I may point out that the views which I expressed in 1888 have been borne out by the facts. In my first paper I wrote as follows: "On the whole there is every reason to believe that the oil industry will develop in the future and will rank amongst the important mineral industries of Burma. Wild ideas about beating or competing with American or Russian oil cannot be too strongly deprecated as being only too likely to prove utterly illusory." In confirmation of the above I simply refer the reader to the chapter on production.

CHAPTER V.—THE OCCURRENCE OF PETROLEUM NEAR YENANGYAT.

SECTION 1.—GEOGRAPHICAL POSITION; AREA OCCUPIED BY THE OIL FIELDS; PHYSICAL GEOGRAPHY.

The small village of Yenangyat, or Yenanchit as it is sometimes spelt, is situated in Lat. 21° 6′ and Long. 94° 51′ E., on the right bank of the Irawadi, nearly opposite the ruins of old Pagan. It is for this reason that this occurrence has sometimes been called the Pagan oil field, or even the name of Paganyat has been substituted.

It seems that the occurrence of oil at this locality has been known for a long time, because Crawford[1] mentions that oil oozes out from the rock at this locality. The members of the mission to Ava [2] apparently visited Yenangyat, and Dr. Oldham was then of opinion that the exploitation of this place might perhaps be projected. It seems that the natives started the construction of pit wells a few years later, but so far the production has been very small.

Wells are dug in three narrow ravines, running, roughly speaking, parallel to each other, north of the village of Yenangyat. The names of these ravines from south to north are—

1. Yenaung-chaung.
2. Ok-Khyaung-chaung.
3. Ywaya-chaung.

[1] Crawford, mission to Ava, Vol. II, page 18.
[2] Yule, mission to Ava, Appendix A, page 320.

The productive wells are all situated in the Yenaung-chaung ravine, but quite recently some successful wells have been constructed in the Ok-Khyaung-chaung ravine.

The area occupied by these wells is very limited, and in no case exceeds a few acres; this, however, by no means indicates the real extension of the petroliferous sands, because the natives have been prohibited by physical difficulties from extending the area exploited by pit wells.

The country around Yenangyat is of the most rugged nature; a hill range, beginning near opposite Singu and gradually rising to 1,184 feet above sea level in the Seikaywa pagoda, runs for about 25 miles from its commencement quite close to the right bank of the Irawadi. In fact its eastern slope forms the bank of the river itself. The eastern slope is steep, very rugged, and is composed of a mass of low hills, possessing a more or less inclined eastern and a steep western slope, and forming a tract of about half to a quarter of a mile in breadth along the river bank. No sooner is this tract crossed than the slope rises quickly and uninterruptedly, frequently forming steep precipices to the crest of the range. The western sides slope more gently, but here we notice also numerous more or less isolated hills, which present a steep eastern and a more or less inclined western face. We will presently see that these features are solely due to stratigraphical conditions.

It is owing to the nearness of the crest of the range to the river bank that the ravines which drain the eastern side are very short, generally very steep at their head, but slightly inclined towards their mouth, and as the magnetic bearing of the range is almost due north and south, all the ravines on the eastern side run due east, affording thus generally very good cross sections. The slopes of the ravines are always very steep, the ravines accordingly narrow, and much twisted about. No more difficult land could be imagined for any industrial undertaking, even small plots of level ground being very rare.

SECTION 2.—GEOLOGICAL FEATURES.

A. The pliocene or Irawadi series.

The lithological characters of the Irawadi series differ in no way from those mentioned in previous chapters. We notice soft whitish or yellowish sandstones, sometimes with strings of hard concretions and ferruginous conglomerates. I have not found any fossil remains on the eastern side of the Tangyi-range, but according to Dr. Oldham's statements, vertebrate fossils are not uncommon on its western side in the valley of the Yaw river. Within the area of the Yenangyat oil field I have not attempted to subdivide the Irawadi series, but I think it is quite possible that a subdivision similar to that of Yenangyoung will be feasible when fossils have been systematically collected in the Yaw valley.

B. The Miocene.

(*a*) *The upper miocene or Yenangyoung stage.*

Lithological characters.—Although in general the same, the Yenangyoung stage as developed near Yenangyat differs in the preponderance of argillaceous beds, while the more sandy beds are subordinate.

The clay is generally of olive green colour, but bluish beds are not unfrequent, and in fact the bed which closes the series has a dark bluish colour. The usual hard concretions in strings or uninterrupted layers are found throughout the series. They form sometimes the top of a hill, the overlaying clay being denuded away.

The sandstones are yellowish or olive coloured, finely grained, generally soft, but sometimes they form hard layers.

Gypsum is very common in all the argillaceous beds.

Palæontological characters.—There was apparently an invertebrate fauna living during the deposit of the above beds, as indicated by numerous fragments of shells. I have, however, never succeeded in finding complete specimens, but some of the fragments apparently belonged to the genus *Cardium*, while others probably represent the genus *Cyrena*.

Subdivision.—Although in the absence of any well defined palæontological features a subdivision based on this evidence is impossible for the present, a certain sequence of strata has been noticed, which seems to continue for a considerable distance in a horizontal direction. In descending over the beds distinguished are—

a. Blue clay, a very conspicuous bed particularly marked by the contrast which its bluish colour forms to the overlying whitish yellow of the Irawadi series. In thickness it is between 40 and 50 feet, and as far as observed it seems to form a very constant horizon within the tract of the Tangyi range.

b. Yellow sandstone; below the above mentioned clay follows a dark yellowish, rather soft sandstone of about 20 to 25 feet in thickness.

c. Olive coloured clay bed of soft, thickly bedded clay of olive colour, containing large quantities of gypsum of about 60 feet thickness. The hard argillaceous concretions of this bed contain occasionally fragments of fossils.

d. Signal hill sandstone; a bed of sandstone of the same character as No. 2, so called because it forms the top of a hill where there is one of the main signals of the Yenangyat oil field survey, thickness about 20 to 25 feet.

e. Olive coloured clay; full of gypsum, the same as No. 3. Thickness about 60 feet.

f. Pagoda sandstone; the same as Nos. 2 and 4; forms the surface of the hill on which the Sehwemyindin Pagoda has been built. It is apparently a little harder than the other beds; its thickness being about 20 to 25 feet.

g. Olive coloured clay, as before; thickness about 40 to 50 feet.

h. Sandstone, as before; thickness about 15 feet.

i. Olive coloured, somewhat more bluish clay, forming a bed of approximately 190 feet in thickness. Strings of hard concretions are very common, covering the slopes in large heaps where the bed crops out.

Forming an opinion from the above section, the total thickness of the Yenangyoung stage cannot be less than 500 feet, and the chief subdivisions seem to form fairly constant horizons as may be seen along the eastern slope of the range (see Pl. XVII).

(*b*) *The lower Miocene beds or Prome stage.*

Lithological characters.—They are the same as already described greyish glauconitic sands alternate with bluish, rather tenacious clays.

Palæontological characters.—The uppermost bed of the Prome stage, a very glauconitic sand, which therefore appears dark green, has yielded a very interesting fauna, which I described in part I of this volume of the memoirs. It is unnecessary to repeat here the list of fossils. It is sufficient to say that they furnish evidence of an unmistakably miocene age of the beds in which they are contained and that their character is purely marine.

Local subdivision.—The boundary between the Prome and the Yenangyoung stages is less well defined at Yenangyat than at Yenangyoung. In fact it may be questioned whether the subdivision of the miocene beds answers the natural conditions best. I have laid the boundary between the Prome and Yenangyoung stages above the first oil sand, but below the thick bed of olive coloured clay No. 9, thus separating the beds characterised by abundance of gypsum in the argillaceous beds from those without gypsum, the arenaceous beds of which generally contain petroleum. As already stated, this subdivision may perhaps be an artificial one, and it would perhaps be better to consider the whole sequence of beds below the Irawadi series as belonging to one and the same series, but it must be borne in mind that the term "Yenangyoung stage" represents only the upper miocene beds which, owing to some characters, chiefly the colour of their sandy beds differ from the lower strata. The Prome stage, as defined, is almost solely known from the deep borings, the insignificant outcrop of the topmost oil sand being too badly exposed to be of any value.

So far it seems that any general subdivision is impossible. The wells have revealed a sequence of arenaceous and argillaceous beds alternating and succeeding each other, but whether these can be considered as constant horizons remains more than doubtful. All we may say is, that the upper Prome stage represents a very thick layer of clay which is subdivided by numerous sandy beds in layers of varying thickness.

The upper beds of the Prome stage have been ascertained for a depth of about 1,100 feet from the surface, which after deducting those beds considered as belonging to the Yenangyoung stage allows about 800 feet thickness for the upper Prome stage. It must, however, be at once added that this by no means represents the total thickness of the stage, which is probably much greater. In fact, it is almost quite certain that the drill is still far away from the base of the Prome stage.

The occurrence of petroleum.—As in the Yenangyoung oil field the petroleum is restricted to arenaceous beds, enclosed between layers of impermeable clay. These sands may contain oil and water together, but the oil has always been found above the water. As may be seen from the boring registers the petroliferous sands vary much in thickness, the thickest bed of sand being recorded in well No. 66, with a thickness of 133 feet, but the quantity of oil it contained was apparently only very small.

So far not less than ten distinct petroliferous sands, following each other in vertical direction, have been recognised, but it seems almost certain that this number by no means represents the total number of petroliferous sands contained in the Pegu series. All the probabilities tend to prove that further petroliferous sands will be found in greater depths, but it is quite impossible to say whether they will be richer or not than those already found. Were it permissible to draw any inference from the strata already known, the conclusion would be, that the lower oil sands are also very poor, but such a statement would be premature as only the drill will give the much desired information. The six oil sands hitherto found in the wells are the following:—

1st oil sand.—This is represented by the same bed which crops out in the Yenangyoung-choung, and from which oil was noticed oozing out by previous visitors. It is from this bed that the pit wells chiefly draw their oil. In well No. 3 this bed was found to have been 70 feet in thickness, in well No. 1, 45 feet; while its thickness is reduced to 18 feet in No. 2, 15 feet in No. 5, and it most probably does not contain any oil in No. 6. The sand was throughout of poor quality.

2nd oil sand.—A layer of sand containing oil, varying from 5 feet in thickness in No. 1, to 20 feet in No. 5; the intermediate strata between the 1st and 2nd oil sand have an average thickness of 160 feet. It must be mentioned that the oil contained in this sand was under such a pressure that it freely flowed to the surface although in small quantities only.

3rd oil sand.—This petroliferous sand exhibits some peculiarities with regard to its thickness, it seems that at well No. 6 this sand attained a thickness of 88 feet containing, however, only gas; to the east, it split up into three different layers, separated by clay partings; the upper one containing water, the middle one gas, and the lower one was apparently dry; in No. 3 it represented a bed of only 5 feet in thickness, separated by a thin argillaceous bed from a dry layer of dark sand of 23 feet in thickness, while at No. 2 the separating layer has disappeared and about 30 feet of dark sand containing a little gas and oil have been observed. It must remain doubtful whether the thin layer of grey sand found in No. 1, above the 3rd oil sand should be considered as a part of it or an independent layer.

It is thus seen that the thickness of these separating clay beds between the 2nd and 3rd oil sand varies, but it may be observed that the 3rd oil sand is found between 50 and 60 feet below the 2nd oil sand.

4th oil sand.—Like the former this bed seems to be very inconstant with regard to its thickness and its petroliferous qualities. In No. 3, where it has a thickness of 25 feet, it has yielded a small quantity of oil, but in the neighbouring well No. 4, where it is divided by an argillaceous bed, it contained no oil; in No. 2 it swells out to 62 feet, consisting of several well-defined beds containing oil at the top and water below ; the oil from the lower layer was slightly under pressure which brought the oil to 175 feet from the surface after being found at 509 feet. In No. 5, where it had a thickness of 10 feet, it yielded no petroleum. In No. 6 two arenaceous beds of 27 and 45 feet respectively are separated by a clay parting of 37 feet thickness ; the lower part of which has been stated to form two distinct beds ; the upper containing a small quantity of oil, the lower gas and water only. It is most probable that the lower bed represents the 4th oil sand, because it corresponds in level to the 4th oil sand which should be found about 100 feet below the 3rd oil sand.

5th oil sand.—This layer is remarkable for the constancy of its thickness ; hardly exceeding 10 feet, it contains oil only in Nos. 3 and 5, while it is dry in No. 1, and contains water in No. 6. It is remarkble that the oil occurring in this sand in No. 3 was under heavy pressure, as it flowed over the top of the well although met with at 513 feet depth from the surface. This bed is about 50 feet below the 4th oil sand.

6th oil sand.—This bed reaches a thickness of about 60 feet in No. 6, where it contains a small quantity of water, in No. 5 its thickness is 45, while it is reduced to 10 feet in No. 3, and from there it seems again to have increased in thickness towards Nos. 1 and 2.

7th oil sand.—A thin bed of not more than 9 feet in thickness hitherto only found in No. 6 well, and probably two thin beds containing gas may represent it in No. 2.

8th oil sand.—This bed has apparently been found in all the wells, it being about 25 to 30 feet. It seems that the thickness of the separating clay bed varies very much, and with it therefore the depth at which it is found below the 7th oil sand. It is smallest in No. 5, but increases quickly towards Nos. 1 and 6.

9th oil sand.—A thin layer of 7 feet found only at Nos. 6, 1 and 2 ; as it is separated from the following by a very thin clay parting it remains doubtful whether it should not be considered as the top portion of it.

10th oil sand.—A very thick bed, which in No. 6 has a thickness of 133 feet, without its lower limit being touched. It has most probably been identified in Nos. 1 and 2, but here the drill did not go so deep as in No. 6; it seems that it contained only a very small quantity of oil.

The occurrence of oil calls for no further remarks, as it has been already mentioned that it seems subject to periodical fluctuations like that of Yenangyoung. The only remarkable feature is the comparatively high pressure prevailing in some of the oil sands, which in one instance at least has forced up the petroleum from over 500 feet.

SECTION 3.—STRATIGRAPHICAL FEATURES.

A.—The superficial sections.

As already stated the ravines, which cut through the hill range at almost right angles, generally afford very good cross sections, but at the present only those in the Yanaung-choung ravine have been examined in detail. From the sections on Pl. XVI, it will be seen that next to the river, the beds of the Irawadi series are exposed along a zone, whose breadth varies very much; it is about 500 to 600 feet in this section. The strata closest to the river bank stand nearly perpendicular, but a little further away, the dip is eastern, but still very high and not below 70° within the boundaries of the Irawadi series. The dip slowly decreases down to about 40° to 45° at a distance of about 1,200 feet from the river, when rather suddenly it changes to about 7° west. The strata form therefore an unsymmetrical anticlinal fold the eastern side of which is marked by high angles of dip, which however rapidly change from about 90° to 45° towards the apex of the anticlinal, while the western side is characterised by a low and very constant angle of dip.

The remarkable topographical features of the Tangyi range are therefore easily explained by its geological structure. The eastern side where we see a mass of rugged low hills with steep eastern slopes, is represented by the steeper side of the fold. On the western side, where the angle of dip is lower, the natural slope is more gentle, and the nature of the ground therefore not so rugged.

The strike of the strata is nearly due north and south, but it seems almost certain, that it changes along the axis of the anticlinal which, instead of running straight, apparently presents an undulating line. Unfortunately I had no time to study this subject in greater detail. It seems to me that the dip of the strata also varies, a matter which might be expected, and it further seems that this results in the formation of a dome like structure as at Yenangyoung, but time did not allow following up this matter. It is to be hoped that the deep borings which are soon to be carried out north of the Yanaungchoung ravine will shed light on this question.

B.—The sections of the drilled wells.

The number of drilled wells in the Yenangyat oilfield, is very small; when I left the locality at the beginning of 1895 there were only six, while a seventh was just going to be constructed. Out of these six, one, No. 4, did not afford any information on the stratigraphical features of the Yenangyat oilfield, because it was drilled on the eastern side of the anticline at a place where the western dip was almost 90°; the result might have been anticipated. Except a thin bed of clay, the drill recorded nothing but sandstone, most probably the same bed which it never left for the whole depth of the well. It is remarkable that the water found in this well was under high pressure, indicating therefore a head of water, which must be found at a considerable distance towards east, as the low and narrow Taungsin ridge, can hardly be supposed to yield the quantity.

The five other wells were drilled in an almost straight line running east and west, that is to say, they were placed on a line which would afford a very good cross section through the deeper strata, and from this point of view the records of these few wells are exceedingly valuable.

From the records it seems that the series affords the same monotonous sequence as recorded from the Yenangyoung oilfield. The correlation of the strata was however much easier, because, to judge from the great regularity of the superficially exposed strata, a similar constancy might be expected in greater depth.

In going through the records the first feature noted is the predominance of argillaceous beds; in fact if we look at the sections on pl. XVII it seems that the sequence consists of an enormous argillaceous series, here and there parted by thin beds of sandstone. The predominance of the argillaceous beds in greater depth is therefore quite in accordance with the character observed in the series superficially exposed.

It will be seen further, that the thickness of the various beds is somewhat inconstant, a fact which has been mentioned already (pp. 79 ff.). Although there seems to be a greater regularity in the horizontal extension of the strata than may be observed at Yenangyoung, it is certain, that a bed may locally attain a great thickness whilst rapidly thinning out in other directions. On the other hand, we may safely assume that certain beds observed in the bores, are of very limited extent.

The first oil sand affords the best instance of the first case; it rapidly increases in thickness from well No. 5, towards No. 3, while it equally rapidly decreases from No. 1, towards No. 2.

As an instance of the second supposition, the two sandy layers found in wells Nos. 1, 2, and 3 between the first and second oil sands may be quoted. It is absolutely certain that these two beds have not been found in No. 5, where an uninterrupted bed of clay separates the first and second oil sand. We are therefore bound to suppose that they thin towards west. These instances could be easily increased in number; it seems for instance quite certain, that the two thick beds of clay, which apparently divide the third oil sand in No. 5, nip out to the west and are replaced by sandy beds, thus forming a thick arenaceous layer which represents the third oil sand in well No. 6.

It is a plausible supposition, that when such changes take place in a transverse direction, they would equally probably be met with in a longitudinal direction. The chief beds of the Yenangyoung stage, as superficially exposed, seem to be opposed to such a view, as they are apparently very constant, but it does not necessarily follow that the same applies to the petroliferous beds. However this question must be left undecided for the moment, but to me it seems highly probable, that the petroliferous beds are subject to irregular changes in every direction. For the above mentioned reasons the identification and correlation of each single bed has been a little difficult, although much less so than at Yenangyoung.

It will be seen from the sections that the various levels in which one and the same bed was found in the different wells are due to the dip of the strata. The lesson taught by the deep wells might have been *a priori* deducted from the structural features at the surface: any well situated east of the crest of the anticlinal is sure to be a failure from a commercial point of view, as, even if not too far off, the high dip will cause the petroliferous beds to be found at such a depth that they are practically inaccessible. Boring operations will therefore have to be more or less to the western side of the anticline, but in this case we see that there are almost insurmountable natural difficulties in the way of reaching a given petroliferous bed, say the first oil sand, at a given distance west of the crest of the anticlinal. As already stated the ravines on the eastern side of the Tangyi range are very short, the crest of the range being close to the river. A well sunk at a spot too far west from the crest of the anticline would therefore have to pass through a large thickness of younger strata before reaching a given bed ; the length of the ravines being very short, and the eastern slope of the main ridge being very steep, suitable sites for wells would be very difficult to find. The range would probably have to be crossed and the well drilled on the western side. In either case, a large series of younger strata would have to be drilled through before the petroliferous sands were reached. Further test wells should therefore be sunk where streams have eroded longer ravines on the eastern slope than at Yenangyat in order to avoid the unnecessary drilling through the unpetroliferous younger beds.

The possibility that wells sunk in more westerly localities will prove unprofitable must, however, not be quite disregarded. It is quite possible that the petroleum rises towards the highest parts of the anticline at Yenangyat and that the lower parts of the petroliferous sands contain no oil, but at the same time it must be mentioned that as proved by the deep wells the petroliferous zone has a breadth of not less than 2,200 feet, chiefly on the western side of the anticlinal, and that so far nothing has shown that its western limit has been touched by well No. 6.

SECTION 4.—FUTURE PROSPECTS OF THE YENANGYAT OILFIELD.

Unfortunately we are not in so good a position for defining the boundaries of this oil field, as we were in the Yenangyoung area, but still certain conclusions may be drawn, partly based on actual observations and partly on inference from other localities.

For the present it is impossible to define the horizontal extent of this field, because the number of deep borings is small, and those which exist are situated along an almost straight line, running east to west in the Yanaung-ravine. These borings have proved, as might have been anticipated from the structure of the beds, that the eastern boundary of the oilfield coincides with the central axis of the anticlinal; from this point the petroliferous sand extends for at least half a mile, and probably more, in westerly direction.

Much less certain are we with regard to the extent of the oil field in a north and south direction, but, if I am right in my conclusions, the field is very limited along this line. It seems that no oil has been found immediately south of the place where the productive wells are situated, and it is almost certain that the wells dug by the natives in the Yawa and Ok-Khyoung ravine hardly produced any oil at all; of course the experience gained by these shallow wells does not prove much, but as we know that the Yenangyoung oilfield is very limited in either direction it is only just to infer that the same holds good for the Yenangyat oilfield. In this case the area of the Yenangyat oilfield would hardly exceed one mile in length, and if we were to suppose that well No. 6 has almost reached the western boundary, the total area of the Yenangyat oilfield would barely exceed half a square mile.

As regards the vertical extent of the oilfield we are even less able to say anything certain about it; but we may assert with safety that if no richer sands are found in greater depth the prospects of the

Yenangyat oilfield are very poor ones. The first oil sand has run almost dry, and those tapped by the deep borings have for the present yielded only a small quantity of oil, although this has been produced by flowing wells. The existence of these flowing wells is the only bright and encouraging feature in the otherwise dark prospect of the Yenangyat oilfield, but as a whole they do not prove much about the future prospects. All that the flowing wells show is that in the sand from which the oil has been drawn a pressure exists which is sufficient to bring the oil in a small stream to the surface.

So far as our present experience goes, nothing indicates the existence of a large quantity of oil, certainly not within the sequence of strata, from the surface to 1,100 feet in depth. As it may be doubted whether the small quantity of oil produced by the drilled wells is sufficient to pay the expenses of drilling, it may be safely stated that, unless the next test wells prove the existence of a rich oil sand, the Yenangyat oilfield will have to be abandoned as unprofitable within a short time.

Chapter VI.—THE OCCURRENCE OF PETROLEUM AT OTHER LOCALITIES IN UPPER BURMA.

A monograph dealing with the occurrence of petroleum in Upper Burma would be incomplete without at least a mention of the other localities in Burma where it is known to occur, although these localities may not have been examined in detail. I do not pretend to say that the following list is exhaustive, in fact I am rather inclined to think that petroleum will eventually be discovered at other localities too, when a thorough exploration of the country has been made. For the present I am able to add the following:—

1. *Bondoung.*—Its geographical position may roughly be defined as about Lat. 22° 30′ Long. 94° 45′. The place where the petroleum oozes out is surrounded by almost impenetrable jungle, which covers the valley of the Patalon-choung, a small feeder of the Chindwin river, about five marches south of the village of Mingin in the Lower Chindwin district. As far as I have been able to ascertain the petroleum

oozes out from a fissure in the rocks, filling a small tank; the strata apparently form an anticline, and most probably belong to the Prome stage. No use has ever been made of the petroleum of this place, a fact which is easily explained by its isolated occurrence.

2. *Yebyu.*—Lat. 21° 35′ Long. 94° 19′. The small village of Yebyu is situated in the Pakkoku district, about 20 miles north west of the village of Pouk. The oil oozes out of several places quite close to the village on the slope of a hill range, which is apparently formed by an anticlinal arch of strata belonging to the Prome stage. The country is densely covered with jungle and therefore very ill-adapted for geological researches. The villagers have extracted the oil in a few shallow pits, but the production seems always to have been very small.

3. *Indin.*—Lat. 23° 0′ Long. 94° 10′. The village of Indin is situated in the Upper Chindwin district, on the eastern bank of the Myittha stream, a feeder of the Chindwin river. Petroleum is said to have been found east of the village. I have not visited the place myself, and am therefore not in a position to verify this statement which is based on information received in 1889 from the subdivisional officer.

4. *Yenan village.*—The small, in 1889 deserted, village of Yenan, is situated at about Lat. 24° Long. 94° 30′ in the Upper Chindwin district, on the right bank of the Yu river, a feeder of the Chindwin. The strata belong to the Prome series or form at this village an anticline, which is cut through by the Yu river. On the top of the anticlinal arch rises a gas well right in the middle of the river while some more wells which bring petroleum to the surface are in the village itself. The indications are, however, very small and the petroleum has apparently never been gathered by the natives.

CHAPTER VII.—RELATION BETWEEN THE OCCURRENCE OF PETROLEUM AND THE MAIN STRUCTURAL LINES OF UPPER BURMA.

It will be seen from the foregoing chapters, that the localities where petroleum is known to occur in Upper Burma spread over a considerable area. The southernmost point is a little south of 19° N. Lat., while the northernmost point is about N. Lat. 24°. Within this area, stretching over five degrees of latitude, petroleum has been found at about 14 different localities. But it is remarkable to note that excepting the most southern localities opposite Prome and west of Thayetmyo, all the others are west of the 95° of longitude and east of the Arrakan Yoma. If we further keep in mind that these localities are not very far east of the 95th meridian it seems almost certain that the occurrence of petroleum in Upper Burma is restricted to a well defined zone of about 40 miles in breadth, and striking along the eastern side of the Arrakan Yoma for a distance of not less than 300 miles. I do not wish to insist that petroleum might not be found outside this zone, but there is a greater probability of finding new localities within this zone than outside of it.

It remains now to be seen how the petroleum occurs within this well defined area, and whether we are able to discover some sort of a rule which might serve as a guide when further researches are made. It has been shown in preceding chapters, that everywhere in Upper Burma petroleum occurs associated with a certain structural feature of the strata, namely, within anticlinal arches. All the petroleum localities are situated on the top of anticlinal arches. Further researches will therefore have to be made in this direction, that is to say, the chief attention will have to be paid to such parts of the petroliferous zone where the strata form anticlinals.

If we enter the occurrences of petroleum on a map of Upper Burma we see at once that they form two well defined lines or belts which perfectly coincide in their strike with the magnetic bearing of the Arrakan Yoma. The eastern oil line or belt we may call the *Yenangyoung anticline*, the western one the *Minbu anticline.*

The Yenangyoung anticline.—The Yenangyoung oil belt includes the following localities, beginning south :—

1. Yenangyoung.
2. Singu.
3. Yenangyat.
4. Bondoung.

It begins about 10 miles south of Minlin-doung and runs in a north-westerly direction for about 30 miles towards the village of Kyoukye: from here the anticline turns somewhat towards east and runs in a north-north-westerly direction *viâ* Singu, Yenangyat, Pinchoung, Bondoung to the Chindwin river which it crosses east of the mouth of the Patolon-choung; its further continuation is unknown to me. The total length for which the Yenangyoung anticline has thus been traced amounts to about 180 miles, but it must at once be stated that along this distance hitherto only three localities, *viz.*:—

1. Yenangyoung,
2. Yenangyat,
3. Bondoung,

have been found which yielded petroleum. Whether petroleum will be found at intermediate places remains to be seen, but there are certain indications of the presence of oil which serve as a guide for further research. The Yenangyoung anticlinal begins as a very flat arch south of Minlin-doung, but the dip increases and soon the arch becomes more and more pointed till it has reached its highest development within the limits of the Yenangyoung oilfield. Further toward north it flattens out up to a few miles north of Kyoukye: from there the arch of the anticline gradually rises, and becomes more pointed till its maximum near Yenangyat has been reached. It again flattens out, till it is scarcely perceptible near the village of Pinchoung, but it is beyond doubt that it rises again towards Bondoung. I have not followed up the Yenangyoung anticline further north than the Pinchoung, but even from the little we know, some valuable inferences may be drawn. I have pointed out that there exists a successive change of the angle of the arch of the anticline, which from being very obtuse gradually becomes acute and then again widens out. The result of this change will be that the top of a given bed gradually rises above a fixed level, and equally sinks back to its former level when the anticlinal arch again widens out. The natural result of this is the formation of a series of turtle back shaped or dome like elevations along the axis of the anticline. It is obvious that the presence of such a structure is revealed by the gradual rise and fall of older strata towards the surface along the axis of the anticline. The Yenangyoung oilfield affords one of the best instances of this kind of structure. So far as it is known at present the petroleum occurs in Burma below these dome like structures. It follows therefore that at such places where along the axis of the anticline only strata of the Irawadi series occur, it would not be advisable to search for petroleum, this substance existing at too great depths for practical exploitation, but that on the other hand, when the older beds as for instance those of the Yenangyoung or Prome stages are found, the probabilities of a successful petroleum find are very great.

Within the area of the Yenangyoung anticline such places as Kyoukye or Pinchoung promise very little success, while at others, as Singu or Yenangyat, the geological conditions are more favourable.

The Minbu anticline.—Unfortunately I have not been able to study the Minbu anticline sufficiently, to pronounce a definite opinion, and the following remarks must therefore be considered to be more or less speculative. It is very probable that the Minbu anticline begins near Thayetmyo, where the occurrences of petroleum at Padouk-bin and Banbyin, may probably belong to the Minbu oil line; it is also quite possible that those opposite Prome belong to the same oil line, but at present there is no proof of it. From Thayetmyo the anticline runs in a north westerly direction towards Minbu, but north of this place its continuity is interrupted on account of the alluvial plain of the Son river intervening. It is very probable that the petroleum springs of Yebyu are situated on the continuation of the Minbu anticline as well as those of Indin and Yenan, but owing to the lack of continuity of observation this must remain problematical for the present. I am also unable to state positively whether similar dome like elevations are formed along the axis of the Minbu anticline and whether it is there that the petroleum occurs. The geological features in the neighbourhood of Minbu render this, however, very probable and besides there is no reason to suppose that conditions different from those of the Yenangyoung anticline should prevail at the Minbu anticline.

We may therefore sum up our knowledge of the occurrence of petroleum in Upper Burma as follow:

(1) The petroleum occurs in the miocene beds or Prome stage.

(2) It has hitherto only been found along the crest of anticlinal arches.

(3) In preference to others, petroleum is found at such places along the above structural lines where the strata form dome-like elevations.

(4) The occurrence of petroleum seems to be limited to a zone of about 40 miles in breadth which runs along the eastern side of the Arrakan Yoma.

These facts may serve as a guide when further search for oil is made. If only those localities are examined where at least one of these conditions is fulfilled, much money will be saved which will otherwise be wasted in fruitless search.

From the foregoing we see that the occurrence of petroleum in Burma forms no exception from the well known rule of its association with anticlinal structure. It is superfluous to dwell here on this subject which has been so ably discussed by Professors Höfer and Orton besides many others. It is sufficient to have shewn that in Burma the occurrence of petroleum conforms to those laws which regulate its occurrence elsewhere.

On the other hand it should be mentioned that the occurrence of petroleum in Burma seems a particularly good illustration of its restriction to dome-like elevation along the axis of anticlinals, a feature to which Professor Orton has already drawn attention.[1]

[1] Rep. on the Geol. Sur. of Ohio 1888, Vol. VI, 1888, page 99.

Chapter VII.—CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES.

In order to arrive at a fair opinion on the chemical composition and physical properties of the Burmese petroleum it will be the best plan to review shortly all the papers that have dealt with that subject, and by summarising their chief results, we shall see how far the different analyses agree as to the composition of the Burmese petroleum.

The earliest reference I can find, is Professor Christison's Analysis of Petroleum from Rangoon;[1] the chief results of his analysis are as follows:—

"The petroleum of Rangoon, at ordinary temperatures in this country, is a soft solid, of the consistence of lard. Its specific gravity, at the temperature of 60° Fahr. is 880, water being 1,000. At the temperature of 86°, it is of the consistence of thin paste, and at 90° it melts completely, and forms a sluggish liquid which acquires more fluidity as the temperature rises. Hence in the East, during the hot season, when it is dug for, it must be in the fluid state, and consequently entitled to its vulgar name ground oil. It has a powerful naphthous odour, different from that of most other petroleums.

*   *   *   *   *   *   *   *

"When six ounces of petroleum were distilled, there was first procured, at a low heat, an ounce of nearly colourless naphtha; then another ounce of straw yellow naphtha, then at a higher heat, about another ounce, much more yellow, yet still fluid at 60° Fahr; next a considerable quantity of a yellowish liquid, which concreted at 60° into a loose mass, composed of numerous crystalline needles and plates, in a yellow naphthous fluid; and as the distillation went on, this matter became more and more solid, but even towards the end was not firmer in consistence than lard. The residual matter in the retort, when the heat had been raised to full redness, was a spongy charcoal.

"The naphtha, when rectified by a second distillation over a lamp and then by a third distillation from the vapour-bath, is limpid and colourless, like sulphuric ether, and its density is 779."

Professor Christison called the crystalline mass "Petroline," the qualities of which he describes in detail, and then adds in an appendix, dated December 1834[2] (the original paper is dated February 1831), that having observed, from an account of Richenbach's discovery of paraffine in Buchner's Repertorium, that the properties of

[1] Chemical examination of the petroleum of Rangoon. Transactions of the Royal Society of Edinburgh, 1836, vol. XIII., page 118 ff.

[2] Transactions of the Royal Society of Edinburgh, 1836, vol. XIII, page 123.

paraffine being obviously identical with those of petroline of the Rangoon petroleum, the latter name appeared unnecessary.

The appendix just referred to was apparently the result of a paper "On the composition of the petroleum of Rangoon," by William Gregory, published in December 1834, in which the author demonstrates that the properties of petroline and paraffine are identical, but, except this fact, not much further light is thrown on the composition of the Burmese petroleum[1].

About twenty years later Messrs. Warren de la Rue and Hugo Muller [2] published the results of their examination of several tons of Rangoon tar, but it cannot be said that these were particularly satisfactory. According to these authors Burmese petroleum possesses the following qualities :—

"At the common temperature this substance has the consistence of goose fat; it is lighter than water, has usually a greenish brown colour, and possesses a slight odour, peculiar, but not disagreeable".

The authors found that by submitting it to fractional distillation yielded[3]—

at 212°F. (100C.)	11	per cent.	volatile oil.
between 230° and 293°F. (110° to 145°C.)	10	„	„ „
320° to 617°F. (160° to 325°C.)	20	„	heavy oil.
at 617° F. 325°C.	31	„	„ „
above 617°F. (=325°C.)	21	„	„ „
Asphalte and coke	7	„	„ „

The authors then analysed the liquid portions of the distillate and found that Burmese petroleum contained at least the following hydrocarbons :—

Benzol	$C_{12} H_6$
Toluol	$C_{14} H_8$
Xylol	$C_{16} H_{10}$
Cumol	$C_{18} H_{12}$

1 An abstract of the papers quoted above is given in Journ. Asi. Soc. Beng., IV, p. 527.

2 Proceedings of the Royal Society of London, 1857, vol. VIII,, page 221 ff.

3 The authors state that the temperature may be raised to 320°F. (=160°C) without materially altering this percentage, we may therefore suppose that the next fraction distilled above that temperature.

In Schaedler's Technologie der Erdöle[1] another analysis of Burmese oil is given, and the name of the analyst as H. Vohl.

The Rangoon oil[2] is here described as follows: "Farbe, grünlich braun; Geruch, eigenartig, nicht unangenehm; Consisteur, von Gänsefett; spec. gew. 0·885—0·890."

It contains :—

Leichte öl	41·40	per cent.
Paraffin masse	50·90	"
Asphalt ruckstand	4·60	"
Wasser und gas	2·80	"
Verlust	0·30	"

If refined the same oil contains :—

Photogen	40·70	per cent.
Schmieröl	40·90	"
Paraffin	6·20	"
Asphalt	4·60	"
Verlust	7·60	"

In 1865 Messrs. Warren and Storer[3] examined some samples of petroleum from Burma which they describe as follows :—

"Upon examination the petroleum was found to be a thick, greasy matter, not sufficiently liquid to admit of being poured from the can which contained it when the temperature of the air was 25°C., but upon being heated, it flowed readily at 30°—33°, and became perfectly fluid at 38°—40°. The color of the mass was yellowish green. It emitted the odor common to the purer varieties of native petroleum; though the odor was but slight and in nowise offensive. The specific gravity of this native petroleum was 0·875 at 29°."

When distilled and heated up to 300°C., 30·46 per cent. of volatile product, or naphtha as it is called, were obtained. This naphtha was further examined and contained :

C_{20} H_{20}	Rutylene, distilling from	170° to 176°
C_n H_n	? " "	180° to 184°
C_{22} H_{22}	Margarylene " "	186° to 193°
C_{24} H_{24}	Laurylene " "	200° to 214°
C_{26} H_{26}	Cocinylene " "	226° to 234°
C_{20} H_8	Naphthaline.	

It probably also contains Pelargone C_{18} H_{18} boiling at about 155°.

[1] Technologie der Fette aund Oele vol. II, Techn. d. Fette und Oele der Fossilien 1877, page 108.

[2] Examination of naphtha obtained from Rangoon Petroleum. Memoirs of the American Academy of Arts and Science. Cambridge and Boston, 1867, new series, IX, p. 208 ff.

Although it is quite probable that for commercial purposes numerous analyses have been made, no further analyses of petroleum from Burma have been made and published in scientific papers so far as I know, up to 1891 when I sent a series of samples of petroleum which I had collected at various places and depths in the Yenangyoung oilfield to the laboratory of the Geological Survey, where they were analysed by my colleague Mr. T. H. Holland. Mr. Holland has published a very elaborate paper on the results of his examination in the Records of the Geological Survey [1] to which I refer the reader.

Quite lately Professor Engler [2] has published the results of his examination of petroleum from Burma which was collected by me at the Yenangyoung, Yenangyat and Minbu oilfield by which further interesting details, especially as regards the commercial value of the Burma petroleum, have been elucidated.

It now remains to group the results of these various examinations, which extend over a period of 60 years in such a way as to arrive at as complete a view on the physical and chemical qualities of the Burma petroleum as can be given at the present moment. It must, however, be kept in mind that this abstract does not pretend to be exhaustive, because, notwithstanding the various examinations, very little is known as to the finer constitution of the crude petroleum for reasons which may be explained easily enough. Analyses of this kind require a large quantity of crude petroleum, collected and hermetically sealed at the place of production. It is quite intelligible that owing to the high temperature of central Upper Burma and the length of transport to Europe, a considerable quantity of the more volatile oils must evaporate before it reaches the hands of the analyst, if the above precaution is not taken. Hitherto only small quantities could be collected under these conditions, and even the analysis of

[1] Records of the Geological Survey of India, 1891, XXIV, page 251 ff.
[2] " " " " 1894, XXVII, page 49 ff.

those, as far as they have been carried out in Calcutta, have been seriously influenced by the climate.[1]

As regards the locality from which the material for the older analyses was obtained I am certainly not wrong if I maintain that it came from the Yenangyoung oilfield and not from Minbu or Yenangyat, for reasons which are obvious. Minbu hardly produces any oil, and the Yenangyat production has up to a recent date been so insignificant that it was consumed locally.

Colour.—By transmitted light the crude petroleum shows various shades of brown, changing from dark chestnut to almost black; by reflected light the colour is a dirty dark green.

All the examiners of Burma crude oil agree in this respect, and to my knowledge there is no exception as far as the petroleum from Upper Burma is concerned. Perhaps there are different shades of dark brown, at different localities, but they are so imperceptible that they may be overlooked.

Specific Gravity.—In the following table I give the figures regarding the specific gravity of the "Rangoon Oil" as it has been ascertained by previous examiners[2]:—

	Name of examiner.	Name of locality.		Spec. G.	Temp.
1830.	Prof. Christison	Yenangyoung oilfield		0·880	60°F.
	H. Vohl	"		0·885—0·890	
1865.	Messrs. Warren and Hofer	"		0·875	84°F.
1891.	Mr. Holland	Kodoung	No. 1	0·875°	85°F
	"	"	No. 16	0·887	"
	"	"	No. 13	0·879	"
	"	Twingon	No. 310	0·863	"
	"	"	No. 306	0·865	"
	"	"	No. 374	0·872	"
	"	Beme	No. 504	0·887	"
	"	"	No. 516	0·892	"

[1] Records of the Geological Survey of India, vol. XXIV, page 251.

[2] B. Redwood, Cantor Lectures on Petroleum and its Products, 1886, page 16, states that the sp. gr. of oil from Minbyin (Burma) is 0·866. No such place is known to me, but it is very probable that the name of the locality is misspelt.

1894.	Prof. Engler	Kodoung	No. 26	0·8726	89°F.
	"	Twingon	No. 62	0·8653	"
	"	Yenangyat	No. 15	0·8214	"
	"	"	(mixed)	0·8160	"
	"	Minbu		1·002·3	86°F.

From the above figures, it is quite obvious that the petroleum of the three localities, Minbu, Yenangyoung, Yenangyat, differs considerably as regards the specific gravity. The Minbu petroleum is apparently the heaviest, its specific gravity being 1·002, then follows Yenangyoung with an average of 0·878—0·869, and the lightest oil is apparently that of Yenangyat having a specific gravity of only 0·819.

On the other hand we see that the specific gravity of the petroleum from one and the same petroliferous tract varies considerably. According to Mr. Holland the specific gravity of the petroleum from Yenangyoung varies from 0·863 to 0·892 at 85·5° F.

After having ascertained that the petroleum occurs in different beds entirely separated from each other and apparently without any communication, the idea occurred to me to inquire whether the unquestionable differences in the specific gravity, are due to the difference of occurrence, in other words, whether the petroleum from the different oil sands is characterised by a different specific gravity. For this purpose I have made a series of observations which require, however, a few words of explanation. All the observations were made with petroleum specially drawn from the wells. In many cases they were repeated because the heavier oils congealed so quickly at the temperature of the oil (72°) that in one instance, that of well No. 135, I noticed the specific gravity change within a few minutes from 32°B. to 38°B., simply from the hydrocarbons of low melting point becoming solid at the above temperature.

With regard to the drilled wells another matter makes observation on the spot extremely difficult; the oil is pumped up, it is therefore so saturated with air and gas, that the bubbles which form on the surface, after the oil is freshly taken from the well, are a very serious obstacle to exact observation, and if in order to avoid this the oil is left standing for some time, the temperature changes, so that this forms a new source of error.

I have arranged these observations into four tables according to the class of depth to which each well belongs, the drilled wells are shown in a separate table:—

I.—Wells below 151 feet in depth.

Serial number of well.	Depth in feet.	Temp. of oil °F.	Density °B.	Spee. G.	Spec. G. at 60° F.
875	90	87	22	0·9210	0·9317
726	100	87	23·5	0·9120	0·9228
776	129	89	19	0·9395	0·9511
879	130	88	22	0·9210	0·9322
202	132	86	19	0·9395	0·9499
			AVERAGE .	0·9147	0·9209

II.—Wells from 151 to 200 feet in depth.

Serial number of well.	Depth in feet.	Temp. of oil °F.	Density °B.	Spec. G.	Spec. G. at 60° F.
886	155	86	16	0·9589	0·9695
674	156	88	16	0·9589	0·9701
623	161	86	22·5	0·9180	0·9284
629	165	87	16	0·9589	0·9697
188	166	87	16·5	0·9556	0·9664
716	170	88	26	0·8974	0·9086
734	185	87	16	0·9589	0·9697
92	188	87	23	0·9150	0·9258
319	189	89	27·5	0·8750	0·8874
731	192	85	16	0·9589	0·9689
691	198	88	14	0·9722	0·9834
670	200	87	15	0·9655	0·9763
306	200	89	31	0·8695	0·8811
			AVERAGE .	0·9279	0·9465

III.—Wells from 200 to 250 feet.

Serial number of well.	Depth in feet.	Temp. of oil °F.	Density °B.	Spec. G.	Spec. G. at 60°F.
307	205	89	30·5	0·8721	0·8837
G 118	205	90	31	0·8695	0·8815
208	206	87	30	0·8750	0·8858
707	210	88	23	0·9150	0·9262
16	224	86	18	0·9459	0·9563
255	229	92	30·5	0·8721	0·8949
273	233	89	31	0·8695	0·8811
442	238	90	28	0·8860	0·8980
91	240	90	28·5	0·8833	0·8953
227	241	89	31	0·8695	0·8811
170	242	90	31	0·8695	0·8815
121	242	88	28	0·8860	0·8972
619	244	88	19·5	0·9364	0·9476
11	246	87	21·5	0·9240	0·9348
23	246	86	21·5	0·9240	0·9344
107	248	88	35	0·8484	0·8596
65	250	85	31	0·8695	0·8795
			AVERAGE .	0·8891	0·9011

IV.—Wells from 251 to 300 feet.

Serial number of well.	Depth in feet.	Temp. of oil °F.	Density °B.	Spec. G.	Spec. G. at 60°F.
280	251	90	29	0·8805	0·8925
469	251	90	26	0·8974	0·9094
115	255	87	33	0·8588	0·8696

IV.—Wells from 251 to 300 feet—contd.

Serial number of well.	Depth in feet.	Temp. of oil °F.	Density °B.	Spec. G.	Spec. G. at 60° F.
93	255	88	29·5	0·8774	0·8886
234	256	88	33	0·8588	0·8700
433	257	90	28·5	0·8833	0·8953
166	257	90	31	0·8695	0·8815
H 62	261	88	32	0·8641	0·8753
135	263	90	32	0·8641	0·8761
134	265	87	32	0·8641	0·8745
21	270	82	20	0·9333	0·9421
119	270	88	24	0·9090	0·9202
26	272	83	24	0·9090	0·9182
410	271	91	31	0·8695	0·8819
239	272	88	32	0·8641	0·8753
22	275	85	21	0·9271	0·9371
287	278	91	26	0·8974	0·9098
361	280	91	30	0·8833	0·8957
66	280	83	32	0·8641	0·8733
G 106	280	89	31	0·8695	0·8811
296	281	89	29	0·8805	0·8921
351	296	89	29	0·8805	0·8921
161	298	90	32	0·8641	0·8761
389	300	91	31	0·8695	0·8819
			AVERAGE .	0·8766	0·8921

V.—Wells over 300 feet.

Serial number of well.	Depth in feet.	Temp. of oil °F.	Density °B.	Spec. G.	Spec. G. at 60°F.
249	303	90	29	0·8805	0·8925
167	303	86	33	0·8588	0·8692
359	312	91	28·5	0·8833	0·8957
			AVERAGE .	0·8742	0·8858

Drilled wells of Kodoung.

Serial number of well.	Depth in feet.	Temp. of oil °F.	Density °B.	Spec. G.	Spec. G. at 60°F.
18	337	89	34	0·8536	0·8652
11	395	88	29	0·8805	0·8917
47	353	87	29	0·8805	0·8913
20	320	88	30	0·8750	0·8862
6	345	86	34	0·8536	0·8640
46	356	85	26	0·8974	0·9074
1	727	88	30	0·8750	0·8862
22	317	89	29·5	0·8774	0·8890
53	365	89	35	0·8484	0·8600
23	422	87	10(?)	1(?)	1(?)*
		AVERAGE (No. 23 EXCEPTED)	.	0·8712	0·8823

Looking through these tables we observe that the specific gravity of the petroleum of such a small area as the Yenangyoung oilfield

* The specific gravity of this oil could not be ascertained at the temperature of 87° which it showed. When coming out from the well, it was a semisolid of the consistency of butter.

oscillates within very wide limits. Even if we disregard for a moment the semisolid oil obtained from Kodoung well No. 23, in which the hydrometer stuck, we see that the specific gravity varies within the limits :—

0·9722 (88°F.) = 0·9834 and (60°F.)
0·8484 (89°F.) = 0·8600 and (60°F.)

the former being observed in pit well No. 691, the latter in the Kodoung well No. 53. The Yenangyoung petroleum belongs therefore to the very heavy oils, a fact which has already been noticed by previous observers. But the figures seem to demonstrate, that within the area of the Yenangyoung oilfield the heaviest liquid petroleum hitherto known has been found. The heaviest petroleum mentioned by B. Redwood comes from Barbadoes, and has a specific gravity of 0·957, which is considerably exceeded by several samples of the Yenangyoung oil.

It may be mentioned, that the examination of these various qualities of petroleum have shown that the Yenangyoung oil forms no exception to Höfer's rule [1]. The lighter coloured the oil, the smaller its specific gravity. The oils of low specific gravity, exhibit in transmitted light a fine dark reddish colour, which changes into dark brown in heavier oils, and is almost perfectly black in the heaviest varieties.

Among these 72 samples of oil, examined with regard to their specific gravity, we find that—

7 or 9·8 °/₀ have a sp. gr.		.	below		16°B.
6 or 8·5 ,, ,, ,,	above	.	16°B.	but below	20°B.
12 or 17·0 ,, ,, ,,	,,	.	20°B.	,,	25°B.
21 or 29·5 ,, ,, ,,	,,	.	25°B.	,,	30°B.
25 or 35·1 ,, ,, ,,	,,	.	30°B	,,	35°B.

These figures seem to demonstrate, that notwithstanding the high specific gravity of some varieties of the petroleum, the very heavy oils are decidedly in the minority. Oil having a specific gravity between 0· 8750 and 0· 8484, takes the largest share, but is

[1] Das Erdol (Petroleum) und seine Verwandten, Braunschweig, 1888, page 29.

closely followed by oil with a specific gravity from 0·9032 to 0·8750.

Turning to the specific gravity of petroleum derived from different depths, the figures apparently prove that the oil becomes lighter with depth, as seen from the following table. The average specific gravity of oil drawn from the

1st oil sand		(wells below 151 feet) is	.	0·9147 = 0·9209 at 60° F.
2nd ,, ,,		,, from 151 to 200 ,,	.	0·9279 = 0·9465
3rd ,, ,,	*a*	,, 201 to 250 ,,	.	0·8891 = 0·9011
	b	,, 251 to 300 ,,	.	0·8766 = 0·8921
	c	more than 300 ,,	.	0·8742 = 0·8858
	d	,, Kodoung wells ,,	.	0·8712 = 0·8823
Grand average of Yenangyoung oil		.	.	0·8917 = 0·9171

However, in going through each of the tables, we find that there are wide differences in the specific gravity of oil which apparently comes from one and the same geological horizon. The explanation is easy; in the pit wells the oil from the upper bed is not shut off when the well is deepened, but is allowed to filter into the well, where it mixes with the lighter oil of the deeper sand and the result is that the oil from the deeper pit wells is in many cases a mixture of oil coming from various sands, but still we can see that, whatever may be the origin of the very heavy oils in the deeper wells, petroleum of lighter specific gravity predominates in them.

In conclusion I may be allowed to say a few words on the practical importance of the specific gravity of the oil. Since immemorial times the petroleum from Burma has been sold by weight; the standard being 100 viss, equal to 365lbs. The production of the deep wells is, however, ascertained in a different way; the oil is conducted into large iron tanks, the contents of which are daily gauged by a measuring rod, and thus the volume, expressed in gallons, attained. The weight is obtained in the usual way, but it is of course quite clear that according to the specific gravity the most varying figures will be obtained. A certain average specific gravity will of course do for all practical purposes, but even that requires a certain amount of correction. Let us for instance assume the average specific gravity to be 0·8917 at the average temperature of 88°F., which the petroleum has when coming out from the well. When this petroleum is stored in the iron tanks, the tropical sun heats it to a temperature of 100°F. and more. The oil expands, its specific gravity changes, and instead of being 0·8917 it will be 0·8869 at the temperature of 100°F.; in other words it will be lighter, and when the gauge shows that 16,000 gallons are in a tank, this quantity converted at the specific gravity of 0·8917 would give 89,170 lbs. while it actually weighs only 88,690lbs., that is to say under the above supposition, there would be a loss of 480lbs. on every 10,000 gallons owing to the expansion of oil under the influence of heat.

Owing to the custom above alluded to, the quantity of the petroleum produced by the oilfields in Burma is recorded in Burmese viss. At the average temperature of the oil when coming fresh out of the well, and at the specific gravity of 0·8917, one barrel of 42 gallons of crude oil would weigh 374·5lbs. As, however, owing to the high temperature of the oil under the influence of the sun the specific gravity is smaller, say 0·8869, one barrel of crude oil will weigh 372·4lbs. For the purpose of comparison it is therefore quite correct to assume that 100 Burmese viss are 1 barrel of 42 gallons; and to convert Burmese viss into barrels, the last two figures must be struck off when the production is given in viss; for instance, 100,000 viss = 1,000 barrels, the error being 2 % in excess.

Volatility.—No special observations have been made with regard to the volatility of the Burma petroleum, but experience has proved that under the influence of high temperature, crude petroleum rapidly decreases in volume. Tank-flats which received their full load at Yenangyoung, show a considerable loss when arriving at Rangoon.

When the petroleum is left to itself in the natural springs at Minbu, it gradually gets more viscous till it resembles asphalt. The high specific gravity of the Minbu petroleum may perhaps be accounted for by evaporation of the lighter oils.

Flashing Point and Boiling Point.—The following are the determinations of the flashing point of the crude petroleum which have been made :—

1 Kodoung	well No.	1 from		feet depth	.	60°F. (Holland)
2 ,,	,,	,, 16	,, 727	,, ,,	.	68°F. ,,
3 ,,	,,	,, 19	,, 359	,, ,,	.	73°F. ,,
4 Beme	,,	,, 504	,, 100	,, ,,	.	132°F. ,,

Mr. Holland states that owing to the difficulty in determining the flashing point of an oil which gives off inflammable vapour at a temperature much below that of the laboratory the flashing point of oils which flash below 73°F. was not determined except in two instances.[1]

Professor Engler has ascertained the boiling point of several samples of crude petroleum with the following results—

1 Yenangyat	well No. 15 from	feet depth boils at .	267°F.
2 ,,	mixed sample	,, .	248°—257°F.
3 Kodoung	well No. 26 from	feet depth boils ,, .	275°—284°F.
4 Twingon	,, No. 62 ,,	,, ,, ,, ,, .	267°—275°F.
5 Minbu	(natural spring)	,, ,, ,, ,, .	572°F.

Consistency and Melting point.—As regards the consistency, the Burma petroleum has been quite rightly termed a viscous oil. This quality is most probably due to its large percentage of paraffine wax. According to Messrs. Warren and Storer it represents a greasy matter, which Christison compares with lard, Warren de la Rue and Hugo Müller with goose fat, at the temperature of 25°C. (=67°F.). I can fully confirm these statements; during the winter months when the temperature of the air at Yenangyoung sinks to about 54°F. the petroleum which collects in earthen pots or small pools congeals and forms a greasy matter of the consistency of lard or goose fat. But when with the rising sun the temperature rises, it becomes liquid and flows readily enough at about 86°F.

This quality is a serious impediment to its being conducted by pipes over long distances, and if found in Europe or under a lower average temperature than that of Yenangyoung, transporting by pipe-lines would be out of the question. During the winter months the

[1] Rec. Geol. Surv. Ind., XXIV, p. 254 (1891).

pipe lines cool to such a degree, that if oil remains therein during the night, it congeals and so effectually clogs the pipe that hours may lapse before it runs again.

Lately Professor Engler has determined the melting point of several samples of petroleum from Upper Burma. According to him,—

1 Yenangyat	well	No. 15	melts at	. . . . .	78·8°F.
2	„	(mixed sample)	„ „	. . . . .	81·5°F.
3 Kodoung	well	No. 26	„ „	. . . . .	87·8°F.
4 Twingon	„	No. 62	„ „	. . . . .	87·8°F.

It would be rash to form a conclusion from these few data, but we may safely say that at a temperature below 75°F. the Burma petroleum becomes solid and forms a greasy matter like lard. The above figures seem also to indicate that the higher the specific gravity the higher is the melting point; however, with regard to this further observations are required.

Chemical composition.—As already stated there still remains much to be done in this direction, because no detailed analysis has been made as yet. We shall therefore have chiefly to deal with the chemical composition from a commercial point of view.

The only elementary analysis of Burma petroleum which I could find has been made by H. Sainte Claire Deville.[1] According to this author "Huile de Birmanie (Rangoon)" of a specific gravity of ·875 at 82·4° F. consists of—

C	83·8
H	12·7
O	3·5
	100.

According to Messrs. De la Rue and Müller [2] the following members of the Benzol series have been found in the crude petroleum of Burma—

Benzol	$C_{12}\ H_6$
Toluol	$C_{14}\ H_8$
Xylol	$C_{16}\ H_{10}$
Cumol	$C_{18}\ H_{12}$

1. Comptes rendus, 1869, page 500.

2. Proceedings of the Royal Society of London, vol. VIII, page 225.

In the table opposite those of the analyses of petroleum from Burma which could be compared are given; for the last four I have to thank Mr. W. Fox, Secretary to the Petroleum Association, London. Mr. Holland's analyses which have been carried out on a different principle could not be compared with them, but it seems that Mr. Holland generally obtained a much smaller percentage of illuminating oil than any other analysis.

These analyses prove that the petroleum from Upper Burma contains from about 50 to 60 °/₀ illuminating oil; Professor Engler mentions however that specially constructed lamps would be required, if a bright flame without smoke were desired.

The percentage of lubricating oil is somewhat smaller, being about 50 °/₀ inclusive of paraffine wax, if we except the Minbu oil, which probably does not exhibit its original composition. The percentage of paraffine wax ranges, according to Mr. Fox, from about 6 °/₀ to 14 °/₀. The approximate average of Burma petroleum would therefore be

Illuminating oil	50 °/₀
Lubricating oil	40 °/₀
Paraffine wax	10 °/₀

It is unquestionable that the lighter oil from Yenangyat affords a larger quantity of illuminating oil, than the heavier oil from Yenangyoung.

	Oil distilling.	Warren de la Rue and H. Müller.	H. Vohl.	Professor Engler.					Mr. W. Fox.			
		Rangoon oil.	Rangoon oil.	Yenangyat well No. 15.	Yenangyat mixed sample.	Kodoung well No. 26.	Twingon well No. 63.	Minbu natural spring.	Yenangyoung.	Kodoung well No. 4.	Beme.	Yenangyat.
Light oils	Below 150°C.	21%	} 40%	17%	18·6%	4·3%	5·5%	nil.	} 57%	54·5%	52%	64%
Illuminating oil	From 150°—300°	20%		49·4%	49·6%	38·8%	38·8%	nil.				
Lubricating oil and	From 300° to 400°	} 52%	40·9%	} 30·8%	28·3%	50·4%	48·7%	76·7%	34·7%	29%	20%	17%
Paraffine wax	...		6·2%						5·96%	14·2%	11·7%	14·8%
Loss	...	7%	12·2%	2%	3·5%	6·5%	7%	21%	...	...	...	...

Part III.

ECONOMIC IMPORTANCE OF THE OILFIELDS OF BURMA.

Note.

Unless otherwise stated all the quantities are expressed in Burmese viss.

1 viss=3·65lbs. avoirdupois.

100 viss=365lbs. oil of the specific gravity. 872=1 barrel of 42 Imp. gall.

To change viss into barrels strike off the last two figures.

Chapter I.—THE YENANGYOUNG OILFIELD.

Section 1.—The community of the Twinzayos and their history.

It is one of the peculiar features of the petroleum industry of Burma, that the right of exploitation of the famous Yenangyoung oilfield has from earliest times been in the hands of a corporation. It is difficult to say how the corporation acquired this right, whether by virtue of a special grant by one of the former Burmese kings, or because its members were the first settlers, in this part of the country, who won the oil. However this may be, it is certain that the Twinzayo community existed as far back as 1797. If we look up Captain Cox's description (see page 11) we find the following note referring to the people who extracted the oil:—

"The property of these wells is in the owners of the soil, natives of the country, and descends to the heirs generally as a kind of hereditament with which it is said the Government never interferes, and which no distress will induce them to alienate. One family perhaps will possess four or five wells. I heard of none who had more, the generality have less; they are sunk by, and wrought for, the proprietors."

Although Captain Cox does not use the term twinzayo, we may conclude from the above description, that in 1797 a certain number of families enjoyed a joint interest in the oil-wells, which were their property; unfortunately Captain Cox does not give the number of families, but supposing there were 24 of them, each of which did not own more than 5 wells, the probable number of wells could hardly have exceeded 100, an estimate which agrees so well with my estimate of 130 wells (see page 178) that I can hardly understand how Captain Cox arrived at the number of 520 wells. Mr. Crawfurd also mentions the twinzayo, but a more explicit reference to the twinzayos is made in Captain Yule's book, although he does not use the term twinzayo, but in a few short but clear sentences he defines the chief rights and customs of the community. He says:—

"The wells are private property, the ground they occupy being owned by 23 families, inhabitants of Yenangyoung, and the representatives, it is believed, of those who first discovered and worked the petroleum. They do not allow any stranger to dig a well, and although a respectable owner stated that they had no written grant or confirmation of their exclusive privilege, yet it is upheld by the local Burmese authorities, and apparently they have sufficient influence to prevent any wells being dug by interlopers in the vicinity of their groups or clusters of wells. The 23 proprietors constitute a kind of corporate body as regards their joint interest in the land, but possess individual property in their own wells. When once a well has been dug, no one else is allowed to dig within 30 cubits of it. No proprietor is allowed to sell or mortgage his well to any one not a proprietor. They mortgage among themselves. Formerly they intermarried among themselves only."

In none of the subsequent descriptions of the Yenangyoung oil-field are the twinzayos mentioned, and except the legendary reference to 24 families, the descendants of the myothugyi who constructed the tank (see above, page 2), the two passages quoted represent the whole of our knowledge of the community of twinzayos during the past ages.

It is only quite lately that the subject had to be taken up in connection with delimitation of the native oil lands, and the following chief rites and customs of the twinzayo community have been ascertained :—

1. There are 24 families which enjoy the joint right to dig for oil in a certain not well defined area close to the villages of Beme and Twingon. They are called the yoya-families and every member of them was entitled to dig for oil. A well owner must necessarily belong to one of these families; no outsider could therefore own a well.

2. The head of one of these families is called the twinzayo, and enjoyed the following privileges. When a member of his family wanted to dig a well, he had to apply for the site to him. In return for the grant of a site, the well owner (twinza) paid a small monthly rent, according to the quantity of oil derived from the well, to the twinzayo. He was, as well as other members of the family, exempted from the so called eight royal services, that is to say, he had not to do forced services or to pay any taxes.

3. The yoyas are divided into male and female yoyas, there being 18 of the former and 6 of the latter. Title and rights of a yoya descend strictly in primogeniture, the male yoya being solely in the male, the female yoya in the female line. The yoya could not be sold to an outsider, but if any twinzayo had no direct descendants, he could, with the consent of the other twinzayos, sell the yoya to a distant member of his family. It is known that at least four yoyas were purchased by junior members of the family, the elder branch having no direct heirs.

4. Among their number the twinzayos elected a head man called twinggimin, who settled disputes, and in later years gave the final permission for digging a well, for which permission he received a small fee.

5. The following customs were observed as regards the wells :—

(*a*) No well was to be nearer than 30 cubits (=48 feet) to any other already in existence.

(*b*) No well was to be sold or mortgaged to an outsider, but the owner could dispose of the oil obtained therefrom in any way he pleased.

6. The members of the Yoya families formerly married exclusively amongst themselves.

Such were their chief customs as they were described to me by several twinzayos, and corroborative evidence of the truth of these statements will be found in the two passages quoted above, but these rules have lately been much infringed upon. Even at the time when the members of the Mission to Ava visited Yenangyoung, complaints about this were made. Later on the customary distance between the wells was no longer observed and the wells were sold and mortgaged to outsiders.

A radical change took place when, about 1852, King Mindon Min perceiving the traffic in petroleum would prove a good means of filling his exchequer, declared the petroleum a royal monopoly. Petroleum could therefore no longer be disposed of at the liberty of the producer but had to be sold at a fixed rate to the farmer who rented the output from the king. The Burmese King thus derived a very handsome revenue from the oil fields, which amounted to about R600,000 per annum between 1873 and 1881, but fell to about half the amount later on. Much interesting light is thrown on the transactions between the twinzayos, the Burmese King and the farmer who rented the output of the oil fields by the letter quoted above (page 27). This letter is in fact the only document we possess regarding these transactions.

It is quite intelligible that from the time when the right of disposal of the petroleum no longer rested with the producers, the other customs which had hitherto been strictly adhered to were infringed upon. A good many outsiders now possess wells, who in former days could not have been able to own them. As it was, however, necessary that some kind of settlement should be arrived at, and the vested rights of the twinzayos be protected, a certain area near the villages of Twingon and Beme was reserved, after a prolonged inquiry, and the well sites therein contained could be disposed of only by permission of a twinzayo. The wells, however, could be sold to any outsider, as well as the oil; not only have the rights of the Burmese diggers thus been protected, but a magnificent present has been made to them considering the limited extension of the Yenangyoung oilfield.

Section II.—The construction of the pit well.

Construction of the pit-wells.—There can hardly be anything more striking, than to read the accounts written about a hundred years ago, describing the operation of digging a pit well, while watching the native miner of the present day digging a well. There is not the slightest difference in the method of a hundred years ago and the present one, and Captain Cox's description could as well have been written in our days.

Having selected a place, a square hole, the sides of which are about 6½ to 5½ feet, is dug; the walls are lined with a wooden casing, which consists of rough split wooden staves, notched at either end to secure a safe jointing. Four of these staves, which answer in length to the length of the sides of the wells, form a square frame. These frames begin at the mouth of the well, and their number gradually increases as the well advances in depth by new ones being added at the lower end of the casing. It is estimated that for every 80 cubits (about 148 feet, the cubit being 22 inches) 1,200 staves are required, that is to say, 300 to each side; the average height of each frame therefore being about 5 to 6 inches; the thickness is hardly more than 2 inches, but being well jointed the frame has sufficient rigidity to withstand the pressure of the sides, although it is common enough that, when the wood is allowed to get old and rotten without being renewed, the casing gives way and the well caves in. At present the price is R10 for 100 pieces. It is hardly intelligible how an observer, otherwise so correct as Captain

Cox, could have been deceived about the construction of the wooden casing as to state that the frames are added at the top, " the whole regularly sinking" as the depth of the well increases. A short reflection would have shown that the friction between casing and rock must be so great that nothing whatever could force down the casing without its being broken. The tools used for digging are simple enough; they chiefly consist of a peculiar instrument called tayuwen, that is to say, a chisel shaped iron shoe fixed to a heavy club shaped wooden handle. The iron shoe is round, slightly tapered and ends in a double pointed edge.

The handle which fits into a hole at the upper end of the bit is club shaped and deeply notched about 6 inches from the upper end. The miner grasps the tayuwen at about half its length with both hands, the upper notched end resting against his shoulder and by putting the whole of his own weight in, drives the pointed edge into the ground loosening it and breaking off small lumps, which are afterwards removed by the hands, filled into a basket, and hauled up. It is of course clear that the tayuwen can only be used in the softest strata, but as not unfrequently streaks of hard sandstone are met with, it remained a problem to me how the miners break through these beds, being deprived of the use of blasting power. During my recent visit I had a chance of seeing how the diggers managed to get through these hard beds, and I must confess it pays great credit to the ingenuity of the Burmese well diggers. A prismatic lump of iron weighing about 150 lbs. (40 viss) pierced at the upper end to allow a rope to pass, is suspended on a beam laid across the mouth of the well. The rope is then cut and the iron falls down striking the bottom of the well with such energy as to produce a considerable hole in the hard rock. As the fall of the iron is so directed that it gradually strikes every point of the bottom, the hard bed is eventually smashed, not however without great loss of time and trouble, as can be well imagined, for every time the weight has fallen down a man is obliged to go down and fasten the weight to the rope that it may be hauled up again.

Wages paid to the miners.—There seems to have been a traditional scale of depth, in force since the last century, according to which the miners were paid, although the amount paid seems to have varied, and certainly has considerably increased since the annexation. The scale runs as follows :—

(1) there is a fixed rate for the first 80 cubits (147 feet) of R105 to R120 ;

(2) the next 10 cubits (18 feet) cost R35 to R45 ;

(3) the next 10 cubits (18 feet) cost R55 to R60 ;

(4) after the well has reached a depth of more than 100 cubits (183 feet) further digging is paid per cubit ; the general arrangement being that for 4 cubits of depth a fixed progressive price is allowed, ranging from R6-8-0 to R12 ;

(5) after the well has reached the depth of 132 cubits (242 feet) another special arrangement comes into force of which I cannot say how far it is in general use; each miner receives R10 a month till the well is finished, whether he is engaged in actual digging or prevented from doing so by circumstances outside his power; but when digging every man has to go down the well 20 times every day.

These data can be arranged in the following progressive scale :—

	Amount paid per cubit of 19 inches.							
	R	*a.*	*p.*		*R*	*a.*	*p.*	
From 0 to 80 cubits .	1	5	0	to	1	8	0	
,, 80 to 90 ,, . .	3	8	0	to	4	8	0	
,, 90 to 100 ,, . .	5	8	0	to	6	0	0	
,, 100 to 110 ,, . .	6	8	0	to	7	8	0	Approximately.
,, 110 to 120 ,, . .	7	8	0	to	10	0	0	Approximately.
,, 120 to 132 ,, . .	12	0	0		...			Approximately.
afterwards by special arrangements.								

As after repeated inquiries I always received the same figures, I believe that the above scale of progressive wages fairly represents the actual amount paid to the diggers in 1890. The statements seem to be the more reliable as they are the same as given to me in 1888.

The system is simple and ingenious, and it seems to me to have been based on a long experience of the condition of the strata to be pierced. The fixed rate for the first 80 cubits seems certainly to indicate that the oil bearing sand was originally found at that depth and that only afterwards when the uppermost bed was exhausted did it become necessary to adopt a progressive scale, because it was not quite certain at what depth oil bearing sand would be met with again.

No detailed information about the wages paid for digging will be found in any of the earlier accounts, than that of Captain Cox. According to his statements the progressive scale per cubit was paid after the first fixed 80 cubits had been gone through without oil being found. The amount of 300 ticals paid for the first 80 cubits and 30 to 50 ticals per cubit seems so enormous that I hardly feel inclined to consider it as correct. There is a general agreement in the Burmese statements that the prices for digging have only quite lately risen, and that in former times the construction of a well was much cheaper. In my opinion it is not likely that a century ago the prices should have been more than three times of their present amount, it being generally agreed that they are now higher than in former times.

Machinery used for hauling up the oil, etc.—If anything has changed since the 100 years, it is not the machinery which is used for letting down the diggers to the bottom of the well and hauling up the oil after the well has been finished. "The machinery used in drawing up the rubbish and afterwards the oil from the well is an axle, crossing the centre of the well, resting on two rude forked stanchions, with a revolving barrel on its centre, like the nave of a wheel in which is a score for receiving the draw rope." Thus runs the description of Captain Cox: "A rude windlass, mounted on the trunk of a tree laid across two forked stems is all the machinery used." With these words, about 60 years later, Yule describes the arrangements for hauling up the oil. Now, one should think that it is quite impossible to make a mistake in describing such a simple machinery, but strange to say such a mistake has really occurred from Captain Cox down to

Dr. Romanis; everyone who gives a description of the machinery invariably states that the cross beam rests on "two" forked stanchions: the woodcuts in Captain Yule's Mission to Ava, page 20, and Dr. Romanis's sketch, both represent two forked uprights. Now there were never two forked uprights, only one of this shape the second one was a simple post into which the cross beam was pegged. The reason for this arrangement is quite intelligible; if there were two forked uprights the axle laid across them was liable to revolve. The friction between axle and supports not being sufficient to withstand the heavy strain of pulling up a man, the cross beam had therefore to be made immovable, and this was easily done by pegging it on one of the uprights.

It is hardly necessary to describe here the machinery in detail, but for the sake of completeness it may be done. Two posts, one of which is naturally forked, are placed at either side of the well; a rude cross beam is laid across these stanchions in such a way that one end of it rests in the fork, while the other end is pegged on the second one. By this arrangement the necessary rigidity is obtained. Two smaller forked branches, serving as supports of a revolving cylinder, are pegged in the middle of the cross beam. The revolving cylinder is made of hard wood, axle and cylinder being made out of one piece; a score for guiding the rope is cut in its centre. When hauling up the oil a leather rope is used to which an ordinary earthen pot is fastened; this is lowered down and is hauled up, when filled by two coolies running down an incline. It seems that formerly "lackered wicker baskets" were used, but they seem to have been superseded for a long time by earthen pots. These pots are of peculiar make, they are ball shaped, with rather a narrow opening at the top, the edge of which forms a kind of neck round which the sling of the rope is fastened. The pots vary in size, containing from 10 to 14 viss, even 16 viss. The same pots are used for carting the oil down to the river.[1]

The lowering of diggers is rather ingenious. For this purpose a strong rope, which ends in two slings, is used, the digger sits on

[1] Lately these timehonoured pots began to be replaced by the prosaic but less fragile kerosine oil tin.

these two slings by passing his legs through them, the knot being over his left shoulder; to prevent shifting a thin rope runs down from the knot across the breast underneath the right shoulder to the back, where it is fastened to the right sling; a second rope is fastened round the hips. At a given signal the coolies holding the other end of the rope gradually lower the digger into the well; the work of hauling him up again is facilitated by an inclined plane which the coolies run down, thus pulling him up more by their weight than by their physical strength; in lowering the weight of the digger assists the coolies coming up the incline. This arrangement necessitates of course a gangway to each well, which must be so situated as to facilitate the work as much as possible. There are often as many as 11 coolies used to haul up a single man, to whose weight of course that of the rope must be added.

Any one unacquainted with the oilfields will be rather puzzled when approaching a well in construction to see the diggers lying around the well with their eyes closed or even tied up (fig. 9)

Fig. 9. Oil well diggers, Yenangyoung oilfield.

The solution is very simple ; as the time of staying down in the well is very limited on account of the fumes, the digger would not have time, coming from the bright glare of the day, to get his eyes accustomed to the darkness in the well before he was going to be hauled up again. By having his eyes previously closed he is enabled to see when down in the well.[1]

Before going down the digger puts a quaint cap made of palm leaves on his head to protect it against stones, etc., falling down from the walls.

The following are observations of the time taken to lower and haul up a man and his actual staying down. Of course the first depends much on the depth of the well, the second on the quantity of gas developed, the temperature, and last, not least, on the physical strength of the digger. General rules can therefore not be established and it is sufficient to give the observations taken at a well of normal conditions.

Well No. 71. Depth 220 feet (146 cubits). Time in seconds.

Observation.	Descent.	Period below.	Ascent.	Total.	Useful time in per cent.
1st . . .	43″	27″	80″	150″	18
2nd . . .	35″	22″	105″	162″	13·5
3rd . . .	39″	18″	124″	181″	10
4th . . .	39″	27″	127″	193″	14
5th . . .	27″	23″	148″	198″	11·6
6th . . .	36″	23″	134″	193″	11·8
7th . . .	31″	22″	150″	203″	10·8
8th . . .	30″	36″	176″	242″	14·8

This table is instructive in several ways—firstly it shows that the total time required for lowering a digger and hauling him up

[1] Within the last two years, the Burmans have hit upon an ingenious method of throwing reflected sun light by means of a small mirror into the well, in order to facilitate the work. I do not exactly know how the Burmans made this invention so to speak, nor when they first used it, but I know for a certain that in 1888 this reflector was unknown to the diggers.

gradually increases, chiefly in consequence of the increased time required to haul the diggers up. We may put down this fact to the fatigue of the coolies, as the observations were taken about 1½ hours before the day's work was stopped. But the most remarkable feature is the exceedingly small percentage of useful time, namely such time as the man stays down in the well engaged in digging. It varies from 18 per cent. to 10 per cent. of the total time, an exceedingly poor result ; it may be that sometimes the percentage of useful time is higher, but we may fairly assume that it is never more than 25 per cent. of the total. Of course this applies solely to wells which have reached the oil bearing strata ; in higher parts where the diggers are not troubled from want of breathing air a man may stay down for hours. But, taken as a whole, it is evident that the process of deepening a well once it has reached the oil-bearing sand is a tedious process, accompanied by much waste of time.

I never heard of any accidents resulting from choking, although the diggers sometimes come up apparently much exhausted and streaming with perspiration.

Approximate value of a well of average depth.—The data above will enable us to arrive at an idea as to the cost of a well of average depth under normal conditions. This calculation will be found useful as a check to statements of the natives about the amount of money invested in the wells, and furthermore it will serve as a basis for the estimate of the capital value of the native oil fields.

A calculation of the probable cost of a well 120 cubits = 180 feet, and 150 cubits = 225 feet, will be quite sufficient.

1. Estimate of cost of a well 120 cubits = 180 feet in depth :

	R
(a) Wages for digging—	
80 cubits at the rate of	200
10 cubits at the rate of	45
10 cubits at the rate of	60
10 cubits at R7-8-0 per cubit	75
10 cubits at R10 per cubit	100
TOTAL .	400

	R
(*b*) Timbering—	
1,800 wooden staves at the rate of R10 per 100 .	180
(*c*) Machinery, ropes, etc., say	30
GRAND TOTAL .	610

2. Estimate of cost of a well 150 cubits = 225 feet in depth:

(*a*) Wages for digging—	
80 cubits for	120
10 cubits for	45
10 cubits for	60
10 cubits at R7-8-0 per cubit	75
10 cubits at R10 per cubit	100
10 cubits at R12 per cubit	120
20 cubits under special arrangement, say R20 per cubit	400
TOTAL .	920
(*b*) Timbering—	
Say 2,400 wooden staves at R10 per 100	240
(*c*) Machinery, ropes, and other accessories . . .	30
GRAND TOTAL .	1,190

We may therefore assume that an estimate of R1,200 for a well up to 250 feet will be very near to the mark.

SECTION III.—THE NUMBER OF WELLS IN THE NATIVE RESERVE.

A. *Period previous to 1888.*—If we look through the earlier accounts about the oilfields we notice a remarkable uncertainty about the number of pit-wells in the Yenangyoung oilfield. This might of course be expected as none of the previous visitors had time enough to go through the tedious task of counting the wells one by one. This was only achieved by the survey, during the years

1890 and 1891, and I am therefore in the position to check with some accuracy the statements of my predecessors. It is clear that the highest number of wells ever in existence must have been recorded by this survey, because in addition to new wells there were all the old wells which must have been seen by previous visitors, and I do not think that a well of, say, about 100 feet in depth can disappear without leaving any trace of its existence behind. It is true some of the old wells have been perfectly filled up again, but by various signs (soil soaked with oil, etc.) it is easy to see that a well once existed where there is now only a shallow hole. Now if we know, approximately even, the age of each well, we shall be able to fix with some amount of confidence the possible number of wells at a certain period in the past. It is, however, difficult to say how far the statements about the age of the well are correct, and to provide for a possible mistake I have allowed a fair margin of age for each well, dividing the wells according to their age in six classes, namely,—

(*a*) wells of 5 years of age and less,

(*b*) wells of 10 years of age and less,

(*c*) wells of 20 years of age and less,

(*d*) wells of 35 years of age and less,

(*e*) wells of 50 years of age and less,

(*f*) more than 50 years of age.

This classification should answer for all purposes. The first class will show all wells dug since the annexation, and after deducting the number of wells in the first two classes we should have the number of wells existing during the period to which the letter of the Burmese Minister refers; the deduction of the first three classes should show the number of wells at Captain Strover's time; and the four first classes being deducted we should find the number of wells in existence at the time when Captain Yule visited the oil-fields.

The following table will show the number of wells in each class for the Yenangyoung field as a whole and for the Twingon and Beme tract separately :—

Table showing the approximate age of the pit wells in the Yenangyoung oil field.

Age of well.	Number of wells.		
	Twingôn.	Bemê.	Total.
Less than 5 years	118	12	130
Less than 10 years	30	6	36
Less than 20 years	162	31	193
Less than 35 years	16	5	21
Less than 50 years	9	3	12
More than 50 years	143	107	250

According to this table there were—

	Twingôn.	Bemê.	Total.	Remarks.
At the end of 1890	478	164	642	Including wells under construction.
In 1888	360	152	512	
In 1880	330	146	476	
In 1870	168	115	283	
In 1855	152	110	262	
Previous to 1855	143	107	250	

It must of course be understood that these figures do not pretend to express the correct number of wells in the year referred to, but that they must only be taken approximately. Now the following table will show the number of wells as estimated by different visitors in the years referred to—

Table showing the number of wells as estimated at different times.

Year.	Name.	Number of wells.	Remarks.
1795	Colonel Symes . .	500	
1797	Captain Cox . .	520	
1826	Mr. Crawfurd . .	200	
1838	Captain McLeod . .	160	Productive wells only.
1855 . . .	Dr. Oldham . . .	200	Ditto.
1855	Captain Yule . .	130	Ditto.
1873	Captain Strover . .	150	
1874	Dr. Friedlāender . .	450	
1879-81	Burmese estimate . .	336	
1886	Sir Charles Bernard .	343	
1886 . . .	Dr. Romanis . .	260	Ditto.

With the help of these figures given above we see that Colonel Symes' as well as Captain Cox's estimates must be wrong, although their concordance seems to speak for their correctness. But we know that in the beginning of 1891 there existed 642 wells altogether. We further know with absolute certainly that 130 of these wells were dug within the last five years, and we further know that at least 120 wells (the so called Royal wells) cannot be older than 30 years. It is even stated that they are not older than 17 years. We know therefore for a certain of 250 wells which are not older than 30 years; most likely, however, not older than 17 years. We would therefore arrive at a number of 392 wells at the utmost on or about the year 1860, that is to say, in round figures 110 wells less than the estimate of about 70 years ago. We would, therefore, be obliged to suppose not only that no new wells were dug during this long time, but that at least 110 wells had disappeared without leaving a trace behind, suppositions which are more than absurd. Both estimates must therefore be considered as highly exaggerated. As regards the next statements from Mr. Crawfurd downwards it is difficult to say whether the figures given represent the total of wells or productive wells only. It may, however, be considered that the figures given by Captain Yule, Dr. Oldham, Captain Strover, and Dr. Romanis represent only the number of productive wells, as their calculations about the quantity of the production is based on the stated number of wells. As it is, however, very unlikely that there were no unproductive or abandoned wells in existence in those days the total number of wells must have been larger. We shall, therefore, have to find out the probable total for the respective years to be able to compare the figures. Now in 1888 the ratio between productive and unproductive wells was 53·4 to 46·5, and I do not think it is unfair if we suppose that the same ratio existed in 1855, as it is only quite lately that it has shifted more in favour of the productive wells.

Under this supposition the following table will show the probable number of productive and unproductive wells in the year mentioned:—

Year.	Name.	Number of productive wells.	Number of unproductive wells.	Total.
1855 . . .	Dr. Oldham . . .	200	174	374
1855 . . .	Captain Yule . .	130	113	243
1873 . . .	Captain Strover . .	150	130	280
1886 . . .	Dr. Romanis . .	200	174	374

Now let us compare these figures with those theoretically obtained. I estimated that there were about 250 to 262 wells in 1855. From the above table we see that if Captain Yule's statement of the number is amended a possible number of 243 wells existed in 1855. This figure agrees so well with my estimate that if we suppose that there were 250 wells, productive and unproductive, we will be very near the mark. Dr. Oldham's estimate of 200 productive wells, which would give a calculated total of 374 wells, is undoubtedly too high; because if we add to this number the number of Royal wells and wells dug since 1885 we get a total of 624 which would mean that since 1855 till 1885 no new wells, except the Royal wells, were constructed. As we know, however, that during this period at least 120 new wells were dug, and if we add this number to the above 624, we get a total of 744 wells supposed to be in existence in 1890. As there are, however, only 632 we see that Dr. Oldham must have overestimated the number of productive wells.

Now having arrived at the conclusion that in 1855 there were hardly more than 250 wells in existence we may fairly assume that the number of 200 as given by Mr. Crawfurd represents the total of wells, which were 107 productive and 93 unproductive wells, and supposing further that the same rate of progress existed during the period 1797 to 1826 as from 1826 to 1855, the probable number of wells at Captain Cox's time was something like 130, of which 70 were productive and 60 unproductive wells.

The number of 280 wells arrived at by taking Captain Strover's statement of 150 productive wells as basis for the calculation agrees so well with the figure arrived at by theoretical speculation that we may take it as accurate as possible.

Dr. Friedländer's statement of 450 wells made only a year later seems hardly to harmonise with it. We shall, however, see that the apparent disparity is the evidence of the correctness of this statement, and on the other hand strongly supports the statement of the natives that the so called Royal wells were dug between 1873 and 1874.

If we suppose that Captain Strover's figure applies to the number of wells previous to the construction of the Royal wells, and if we further suppose that Dr. Friedländer visited the oilfields after their construction, and if we add to their number (120) that of total number according to Captain Strover, namely 270, we receive 390, say 400 wells, a figure which is pretty close to that given by Dr. Friedländer.

The next estimates, that is to say, those of the Burmese Minister (336 wells), of Sir Charles Bernard (343 wells), and Dr. Romanis (374 wells) are undoubtedly too low, because I ascertained at the time of my first visit the existence of the old numbering of the wells which may partly be seen still, according to which there were at least 538 wells. It has been stated that the numbering was done immediately after the annexation; however it may be, whether it was done in Burmese times or later, the figure of 538 wells agrees so well with the number of 512 wells, theoretically supposed to be in existence in 1885, that the two statements referring to the number of wells in 1886 must be below the mark, which applies probably also to the statement for 1879-81. The number given by me in 1888 is also a little too low, as I confess that I must have overlooked some of the abandoned wells.

The following table will show the probable number of wells in existence in the years referred to, those figures which are calculated being marked by*:—

Table showing the probable number of productive and unproductive pit wells in the Yenangyoung oilfield during different periods.

Year.	Number of productive wells.	Number of unproductive wells.	Total number of wells.
1795-97	70*	60*	130*
1826	107*	93*	200
1855	130	113*	243*
1873	150	130*	280*
1874	214	186*	400*
1885	245	289*	538

B.—From 1888 to the beginning of 1895. When I first examined the Yenangyoung oilfield in 1888 no map of this area was in existence, in fact we may say that this tract was almost a *terra incognita.* To arrive under such circumstances at a fairly correct idea regarding the number of wells, proved a difficult task. I was obliged to prepare a map first, which was done by pacing and measuring the angles with the compass and to enter on this map the position of the wells. To increase the difficulties under which my work was carried out was the unsettled state of the country. I may therefore have overlooked some wells, but on the whole I think the number given is fairly correct.

During the year 1890-91 a thorough survey of the Yenangyoung oilfield was undertaken, during which the greatest care was taken to ascertain the number of wells in existence, and the locations of those which had been abandoned and were eventually filled up. The wells were carefully numbered and their positions accurately fixed.

Generally we may divide the wells into two classes, productive and unproductive, and although the former are those of economic value, the study of the latter is not without interest, inasmuch as it reveals some features of the evolution the petroliferous tract has taken.

The productive wells require no further definition, but a short explanation is necessary as to what I regard as unproductive wells. The foremost among the latter class are of course such wells as once yielded petroleum, the supply of which has run so short that they have been abandoned. By want of care the casing broke down and the walls sliding, eventually funnel shaped holes were formed, which in many cases have been entirely filled up again. The second in importance are wells under construction, *viz.*, wells which have not reached the petroliferous sand, but which are energetically deepened. Such wells are apt to become a most important factor in the future, although not productive at the time.

The third class are well sites, *i.e.*, places which have been selected for the future location of a well. The owner of such a well site may not avail himself for the moment of his privilege, but at any time he has the right to dig a well at the spot selected, and for this reason the well sites were also recorded. They may or may not become an important factor in future with regard to the production. The following table will show the number of wells for the years 1888, 1891, 1893, 1895, but it must be remarked that no record was kept in 1888 of well sites or wells under construction :—

		1888.	1891.	1893.	1895.
Productive wells		281	377	406	519
Unproductive wells.	Abandoned wells	245	235	234	239
	Wells under construction	...	32	23	151
	Well sites	...	133	114	281
	TOTAL	526	777	777	1,190

It will be convenient to deal with each class of wells separately and to examine the changes it has undergone during the period from 1888 to 1895.

A.—Productive Wells.

In 1888 I recorded 281 productive wells, and although I may have overlooked some abandoned wells, I am quite certain that the above figure represents the actual number in that year.

Since that time the number of productive wells has been steadily on the increase ; but it seems that the number increased by leaps and bounds rather than by gradual progress. This is easily explained, as between 1888 and 1891 the native well diggers were allowed to go on digging new wells, while in 1891 the construction of new wells was prohibited, pending the settlement of the rights of the Twinzayo Corporation, and only those wells which were actually under construction in that year were allowed to be finished. Owing to the complicated nature of the rights in the native oilfields the period of settlement was a prolonged one, and during its duration only such new productive wells could be added as had been under construction at its commencement. This explains the very small increase of 29 productive wells during the period 1891—93.

At the end of 1893 a satisfactory settlement of the rights of the twinzayos having been achieved the construction of fresh wells was again permitted, and the natives availed themselves of their privileges in such an energetic manner, that between the last half of 1893 and January 1895, 113 new productive wells had been constructed.

So far this seems to indicate a very prosperous state of the native oilfields at present, but we shall see that far from being so, this very increase of the number of the productive wells is an indication of the setting in of the decline of the native petroleum industry.

The pit wells may be examined in two ways, *viz.*:—

(1) with regard to their depth,
(2) with regard to their production,

both sides will give us full information as to the state of the native oilfields, and if thoroughly gone into, some conclusions may be drawn which have been further elaborated in the section dealing with the future prospects of the oilfields in Upper Burma.

(*a*) *Depth of the pit wells.*

It is a general belief among the native well diggers that a well sunk in one of the ravines which intersect the oil tract of Twingon reaches the petroliferous sand within the same depth as a well constructed on the plateau. On the face of it this seems highly absurd, as one would feel inclined to think that a well in one of the ravines being so much nearer to the petroliferous sand must strike it sooner than one on the top of the plateau.

It is, however, a fact that such is really the case, and may be explained. Observing that the Twingon tract is situated on the arch of an anticline, and that the area was mostly intersected by longitudinal ravines, *i.e.*, such running parallel to the strike of the strata, the curious phenomenon seems to be easily explained by the natural dip of the strata.

I have adopted this view in my former two papers, but I must confess that it never fully satisfied me, as there were many cases which seemed to be opposed to this view. In the geological description I have, however, demonstrated the existence of three successive oilsands, and the restriction of the two upper ones to a very limited area. The wells in the ravines, therefore, most probably did not touch the 1st and 2nd oilsand at all, or if they did, they were not oil-bearing, and the diggers had to go deeper till they reached the level of the 3rd sand. It must therefore be supposed that two wells of the same depth, one being situated on the plateau, the other in the ravine, draw their oil from two different oilsands, following each other in vertical position. Of course the natural dip of the strata must not be entirely disregarded, as it is almost certain that a well situated farther from the centre of the anticline will traverse the strata diagonally, and thus reach a given horizon at a greater depth than if constructed on the axis of the anticlinal.

The greatest depth I recorded in well No. 411 was 317 feet from the surface. It seems almost certain that this represents the maximum depth to which the Burmese well digger is able to go. The noxious gases at that depth render any length of stay in wells without artificial ventilation impossible ; but even if the Burmans were to resort to this, the crude way in which they would certainly carry it out would prove most ineffective. Besides the long time which lapses in hauling up a man from that depth by the usual Burmese method, is so considerable that it would prove very expensive to deepen a well of over 300 feet only a couple of feet. As the return is also very uncertain very few wells have reached a depth beyond 300 feet, and we may take it almost for granted that 320 feet is the limit to which the Burmans can go with their method of digging. The practical importance of this fact is obvious, and conclusions which may be drawn from it have been already dealt with in a previous section.

I found it convenient to divide the wells into five classes, according to the depth which they have attained,—such a division would be perfect if we were able to refer all the wells to a common level, a task which is, however, almost impossible, unless the most careful levelling were resorted to. As the case stands, a well which is situated in a ravine and which is, say, 200 feet in depth is classified in that class, although it ought to be included in the same class with a deeper well, when the latter is situated on the plateau. I have, however, found that such a correction would not materially alter the results, and that for all practical purposes the classification, as suggested in my former papers, is quite sufficient. The classes were—

I	Class,	all wells below 151 feet in depth.	
II	,,	wells from 151 to 200 feet in depth.	
III	,,	,, ,, 201 to 250 ,, ,, ,,	
IV	,,	,, ,, 251 to 300 ,, ,, ,,	
V	,,	,, more than 300 ,, ,, ,,	

According to this classification the following numbers of productive wells were registered in :—

Class.	Depth.	1888.	1891.	1893.	1895.
I .	Below 151 feet	33	59	36	86
II .	From 151 to 200 feet. . . .	67	97	86	127
III .	From 201 to 250 feet. . . .	143	187	187	192
IV .	From 251 to 300 feet. . . .	35	33	97	105
V .	More than 300 feet	3	1	...	9
	TOTAL .	281	377	406	519

Three features are very striking; the large increase of the shallower wells, namely, such of 200 feet and under since 1888, and the equally large, if not larger increase of the deeper wells and the remarkable constancy of the medium depth wells.

In 1888 the shallower wells (I and II Class) aggregated 100, a figure which increased considerably in 1891, but fell off again in 1893 when no more fresh wells were sunk, and the existing ones gradually deepened. In January 1895 the shallow wells reached the unprecedented number of 213, that is to say, an increase of over 100 per cent., as compared with 1888. The reason of this enormous increase is easily explained; after 1893 the new part of the Twingon reserves, namely, its south-western corner which hitherto contained only a few wells, was rapidly exploited, because some rich wells were found in this part, which drew their oil from the 1st oil sand. Nearly all the new wells, to the number of 107, which have been constructed between the end of 1893 and January 1895, are situated in this part, and as the 1st and 2nd oil sand have not shown signs of exhaustion, they still belong to the shallow wells. If we deduct the number of these newly constructed wells, from the total, we obtain 106, that is to say, a figure which very nearly corresponds with the number of the shallow wells in 1893, *viz.*, 126. We may therefore suppose that the number of shallow wells in the older part of the oilfield has remained almost the same, showing a small decrease which will presently be explained. In other words we may deduce from the above figures the fact, that no fresh wells have been constructed in the older parts of the oilfields, which obtained their supply of oil from the first or second oil sand.

The next very striking feature is the enormous increase of the deeper wells since 1888, in that year 38 were recorded altogether, in January 1895 there were 114, or an increase of 200 per cent.

This also can be easily explained, a pit well is generally deepened when it begins to fall off in production; there was no particular need of increasing the depth previous to 1891 when the same quantity could be attained by increasing the number of wells. When no fresh wells were allowed to be constructed, the falling off of the production of the individual wells immediately necessitated steps to be taken to secure their former production. The steps naturally resulted in an increased depth, and we see towards the beginning of 1893 the number of the deeper wells almost trebled since that year, when the construction of fresh wells not only kept up, but considerably increased the production, the necessity of deepening the older wells was less pressing, and we see, that since 1893 their number has only been increased by 17.

The steadiness of the number of middle class wells, *viz.*, those between 200 and 250 feet, on which as we shall presently see, the production chiefly depends, is remarkable. The only increase is recorded between 1888 and 1891, when 44 were added to their number. These wells, which derive their supply from the 3rd oil sand remain therefore for a longer time productive without the necessity of being increased in depth, and whatever number is taken off by the wells becoming deeper is added by the same number of shallow wells advancing to the middle class stage.

In discussing the shallow wells I stated that they showed a small decrease of 20 in 1895 as compared with 1893; now if we add this number to the total of the III and IV class wells, we obtain the number of 304 or nearly exactly the same figure to which the sum of the III, IV and V class wells amounts in 1895, *viz.*, 306, or, in other words, the depth of the wells has been only slightly increased since 1893, no necessity having arisen for doing so.

2. *Production of the pit wells.*—In my two previous papers I classified the productive wells into six classes according to the quantity of petroleum each well yielded per day. This same classification will be again followed as it has been proved the most convenient form to examine the pit-wells from this point of view. The wells are, therefore, divided into—

1st	class	wells	yielding	less than	21	viss	per	day.
2nd	,,	,,	,,	from	21 to 50	,,	,,	,,
3rd	,,	,,	,,	,,	51 to 100	,,	,,	,,
4th	. . . .				101 to 150			
5th	. . . .				151 to 300			
6th	. . . .			more than	300			

The following table will show the number of each class of wells as recorded in the years stated :—

Class.	Daily Production.	1888.	1891.	1893.	1895.
1	Wells yielding less than 20 viss . .	128	166	142	192
2	" " from 21 to 50 viss . .	54	94	110	140
3	" " " 51 to 100 viss . .	52	76	85	103
4	" " " 101 to 150 viss . .	27	24	33	54
5	" " " 151 to 200 viss . .	17	17	31	28
6	" " more than 300 viss . .	3	...	5	2
	Total .	281	377	406	519

(*a*) *Wells of the 1st class.*—From the above figures it will be seen that in every year in which the observations were taken those wells which yielded 20 viss and less per diem are far in the majority. The percentage of the total number was in

1888 . . . . 45 %
1891 . . . . 44 %
1893 . . . . 34 %
1895 . . . . 37 %

It cannot be considered as a very promising sign that the poor wells form such a large part of the total number, which amounted to nearly one half in 1888 and has never been less than one-third. The percentage seems to be steadily on the decrease up to 1893, but since then an increase has again been noted.

(*b*) *Wells of the 2nd and 3rd class.*—A steady increase is recorded in wells of the 2nd class, inasmuch as they have increased in number from 54 in 1888 to 140 in 1895; it will, however, also be noted that the chief increase took place from 1888 to 1893 when their number more than doubled. The same applies to the wells of the 3rd class showing also an increase of nearly 100% in 1895 against 1888. The percentage of the middle class wells was as follows, in

1888	37 °/₀
1891	45 °/₀
1893	48 °/₀
1895	46 °/₀

Although we notice a certain increase since 1888, the percentage has kept very steadily a little below one-half of the total for the last four years.

If we consider the wells of the first three classes together we notice that not only do they form the vast majority of the productive wells, but that their percentage keeps remarkably steady, being 82 °/₀, 89 °/₀, 82 °/₀, 83 °/₀, in the years referred to. If we were to judge the prospects of the oilfield from these wells it could not be asserted that they were very promising ones, when the overwhelming majority of the wells yields less than a barrel a day.

Wells of the 4th, 5th and 6th class.—There is also an increase in number since 1888, particularly noticeable in the wells of the 4th class, which have exactly doubled, but on the whole their percentage has not much changed, being in no case more than 18 °/₀.

We may therefore conclude that roughly 2 out of every 5 wells, constructed according to the Burmese method, will yield less than 20 viss per day, 2 between 20 and 100 viss and only 1 more than 100 viss. It therefore fully bears out the conclusions I arrived at with regard to the production of the pit wells in my first paper.

In my former papers I found it useful to give in a separate table the total daily production of each class of wells. I think, however, that such a table is superfluous, as it conveys no other ideas beyond those already deduced from the number of the wells in each class. Each class being established on the base of a certain fixed position, it is clear that the aggregate production chiefly depends on the number of wells contained in each class, and if we were to multiply those with the average for each class, we should arrive at a fairly correct idea as to the daily production of each class, Much more important is the relation between depth and production, that is to say to investigate the aggregate daily production of the wells belonging to the same class of depth. Such an examination will convey a very good idea as to which of the oil bearing sands chiefly contributes towards the supply of petroleum.

The following table will show the aggregate daily production of each of the five classes of wells as they were arranged on page 183 :—

Class.	Depth.	1888.	1891.	1893.	1895.
I	Less than 150 feet	984	1,384	1,132	2,795
II	From 151 to 200 feet	2,511	3,407	3,093	6,272
III	From 201 to 250 feet	9,255	10,497	13,203	11,825
IV	From 251 to 300 feet	2,754	2,557	9,110	8,064
V	More than 300 feet	365	70	...	745
	TOTAL .	15,869	17,915	26,538	29,701

Two features are the most striking in the above table, the preponderance of the production of the III class wells and the marked increase in the production of the shallower wells in 1895, while that of the deeper ones shows a slight, though noticeable, decrease. As before it will be useful to consider the different classes by themselves.

(*a*) *I and II class wells.*—In 1888 the aggregate production of these wells amounted to 3,495 viss or 23°/₀ of the total, there was a slight rise in 1891, and a distinct decrease in 1893, while in 1895 the production rose to 9,067 viss equal to 35°/₀ of the total production, that is to say, within about 1½ years the production had more than doubled, and almost trebled as compared with 1888.

As explained this is chiefly due to the exploitation of the south-western corner of the Twingon oilfield, which had hitherto been scarcely worked, and where the 1st and 2nd sand still contained a good quantity of oil. If it had not been for this the production would most probably have decreased, as will be seen by the examination of the other figures, because notwithstanding the enormous rise of over 100% in the production of this class of wells the increase of the total production has only been 3,163 viss or about 18%.

If we assume that the wells of the first two classes in the older part of the field yielded the same quantity in 1895 as in 1893, we find that the increase in this class is 4,842 viss, which represents very nearly the output of the 107 new wells.

(*b*) *III class wells.*—The wells of this class chiefly drain the 3rd oil sand, and since regular observations were made, they have proved to be the chief supporters of the petroleum production. Their shares were, in

1888	58·3%
1891	58·5%
1893	49·7%
1895	39·5%

We see therefore that, notwithstanding the preponderance of the III class wells as regards the absolute number, their share in the production has been slowly but steadily on the decrease since 1888, and the balance has shifted more in favour of the other wells. In 1893 the deeper wells had to supply the deficit, in 1895 the difference was nearly equally divided by the shallower and deeper wells. Now if we keep in mind that with the exception of a few, the III class wells are situated in the older part of the oil fields, this is by no means a favourable indication for the future. In fact we may assume that within the area of the native reserve the 3rd oil sand begins to show signs of exhaustion, and the wells draining it begin to fall off in production.

(*c*) *IV and V class wells.*—Much remains to be said about these wells: in former years up to 1891 their contribution towards the total production was small, being 19·6% in 1888 and 14% in 1891; after 1891, for reasons already explained, their share suddenly rose to the extent of 34·3%, but since that time it has again slightly fallen off to 29·7% chiefly on account of the recently constructed shallow wells which fully supplied the production without the necessity of deepening the wells. We may, however, expect a rise after the production of the shallow wells has declined, a possibility which, in my opinion, is to happen very shortly if the exploitation of the 1st and 2nd oil sand in the small area of the south western corner of the Twingon reserve goes on at the same rate as it has been doing during the last year.

More instructive even than the aggregate production of each class of wells is the investigation of the average production of the individual well in each class, as shown in the following table. The average production of a well in each class amounted to in Burmese viss :

Class.	1888.	1891.	1893.	1895.
I	26·6	23·5	31·4	32·5
II	37·2	35·1	36·0	49·3
III	64·7	56·1	70·6	61·5
IV	78·7	77·4	94·0	76·8
V	120·6	70·	...	82·7
General Average .	56·6	47·5	65·6	57·2

The most striking feature of this table is the remarkable change in the general average, from 1888 to 1891 there was a distinct decline which was followed by a rapid rise in 1893, the average for 1893 is in fact the largest average yield ever noted, and it is certainly no mere coincidence that such a high average was obtained, at the same time when impossibility of digging fresh wells had led to the deepening of the existing wells, and by this increase of depth new parts of the oil sand were opened which yielded a good supply of petroleum. Since 1893 a distinct falling off has again set in amounting to 8·4 viss per well. This seems small enough, but let us realise how much it actually means; there are 519 productive wells, which if the average for 1893 were kept up would produce 1,21,788 viss per mensem more, or instead of an average turn out of 7·9 lakhs of viss there would be a production of 9 lakhs of viss.

The decline in the average yield of 1895 can certainly be attributed to a decline in the yield of the deeper wells which is by no means balanced by a corresponding rise in the yield of the shallow wells. In fact it may almost be considered as certain that if that rise had not happened and if the shallow wells had retained the average production recorded during the years 1888, 1891 and 1893, *viz.*, 34·9, 30·7 and 34·6 respectively, instead of rising to the average of 42·5 viss, the present rise in the production would not have happened at all, but instead of it, we should probably have seen a decrease in the production.

That such a rise in the average production of the shallow wells has taken place, is as already pointed out solely due to the exploitation of the 1st and 2nd oil sand in a part of the Twingon Reserve by means of a number of recently constructed wells.

(*B*) *Unproductive wells.*

(1) *Abandoned wells.*—The remarkable feature in connection with the unproductive wells is the apparent constancy in the number of abandoned wells, which as will be seen from the table on page 180 has undergone very slight changes only. This may be explained thus: during the years 1891 to 1893 some of the better preserved abandoned wells were repaired and deepened, thus changing them into productive wells while others which could no longer be kept up fell in disuse. This fact has been recorded in several instances, but it would be useless to mention each case in detail, but for reasons already explained, I fear that there will be a considerable increase in the number of unproductive wells, within the next few years.

The proportion between productive and abandoned wells may be roughly expressed in the following manner; for every two abandoned wells there were :—

2	productive	ones	in 1888.
3	„	„	in 1891.
4	„	„	in 1893.
5	„	„	in 1895.

More accurately expressed the figures stand as follows :—

53 : 47 in 1888.
61 : 39 in 1891.
63 : 37 in 1893.
65 : 35 in 1895.

It is therefore evident that the proportion is a fairly constant one which has during the last years slightly changed in favour of the productive wells. The proportion is of some importance, as it offers means for estimating the number of wells during the former years and thus checking the statements regarding the number of the wells in the Yenangyoung oilfield made by former visitors (see above, page 178).

2. *Wells under construction.*—In former years when the demand for petroleum was not so large, the number of wells under construction was apparently a small one, and probably new ones were only constructed when the old ones had fallen in disuse. Unfortunately the figures for 1891 and 1893 cannot be considered as proof because, as I have already pointed out, the construction of fresh wells was stopped during those years, and only those which were already in progress were permitted to go on. It is, however, reasonable to suppose that it never attained anything like the number at the beginning of 1895, *viz.*, 151; if the progress had been going on at anything like this rate during former years the abandoned wells ought to exist in thousands instead of in hundreds. We may therefore safely suppose that the present enormous number of wells under construction is something unusual, and that the next years will see a decided decrease.

3. *Well sites.*—The existence of the well sites is solely due to the recent settlement of the native reserves, which has made the well

site a marketable commodity. In former times there was no such competition for securing the best places as now exists; when a man desired to dig a well there was ample room for it, and he had not to secure a place for a well years before he was in a position to begin to dig it. Now a well site is worth about R50 and readily sold for this price to any applicant by the twinzayos. But as not every buyer is in the position to pay at once the expense of constructing several wells, he secures perhaps a dozen well sites, while he actually constructs only one well. Of course the number of well sites within the reserves is limited, as it depends on the area of the reserves; it was found convenient to allot two square chains to every well site, and the area of both the Twingon and Beme reserves contains 450 acres, hence the theoretically possible number of wells amounts to 2,250 ; of these 1,190 are already in existence, thus allowing space for 1,060 more well sites ; in other words, more than half the allotted area has been disposed of. Owing to the physical constitution of the ground it will, however, be extremely difficult, if not impossible, to divide the remaining area in such a way that 1,060 additional wells could be conveniently located, in fact it is more probable that the actual number will be far below that figure ; however, if the remaining land were to be sold at the present rate of, say, 200 well sites a year, it would be disposed of in less than five years.

We may now sum up our review of the changes the pit wells have undergone during the last seven years in a few words.

There has been a great increase in the number of productive wells, their depth, and their production since 1888. Although this seems to indicate a very prosperous state of the native oil fields such view is a deceptive one, because the increase of production has solely been the result of the construction of a number of fresh wells in a hitherto hardly exploited part of the reserves, while, on the other hand, those wells situated in the older parts of the field, which formerly chiefly supplied the production, show a distinct decline in yield notwithstanding their increased depth.

SECTION IV.—THE PRODUCTION OF THE PIT WELLS.

A.—Period previous to 1886.

The question of the quantity of petroleum produced by the Burmese oil fields has of course attracted the attention of the visitors since the earliest times. There is hardly any account in which the authority does not attempt to estimate the production by a more or less sagacious method. The general mode adopted is to multiply the number of productive wells by the average yield per well. Fair results could certainly be obtained in this manner if the actual average yield per well was known with accuracy; any erroneous statement must naturally be of great influence as regards the estimated production. Now as far as my experience goes, it is extremely difficult to obtain an accurate estimate of the average yield per well by relying only on native information; the data thus received vary so much that their value is more than problematical. The following table will show the figures stated to express the average yield per well since Captain Cox's time:—

Table showing the estimated daily average yield per well.

Year.	Name.	Average daily yield in viss.
1797	Captain Cox	300
1826	Mr. Crawfurd	235
1838	Captain McLeod	36
1855	Dr. Oldham	180
1855	Dr. Oldham, different estimate	62
1855	Captain Yule { Twingon	220
	Captain Yule { Beme	40
1873	Captain Strover	100
1879-81	Burmese Minister	50

The figures in this table differ so widely that it is not difficult to see that some must be erroneous. Unfortunately there are no means of checking them, all what I can do is to express my personal opinion. I believe that Captain Cox and Mr. Crawfurd's estimates are too high, while it is quite certain that Captain McLeod's estimate is much too low. As regards the estimates of the members of the Mission to Ava, I believe that Dr. Oldham's first estimate is too high, while his second is probably a little too low. It is further beyond any doubt that the average of 200 viss per well in Twingon, as estimated by Captain Yule, is too high, while his estimate for Beme is equally too low. Captain Strover's estimate seems fairly correct, while that of the Burmese Minister seems apparently too low.

It seems perfectly clear that estimates regarding the monthly production will still more widely differ, not only on account of the estimated average production per well, but chiefly because the number of productive wells greatly varies according to the different observers, as already pointed out on page 175.

Now the following table will show the monthly production of the Yenangyoung oil field, as estimated at different times :—

Table showing the monthly production of the Yenangyoung oil field during the period 1795 to 1896.

Year.	Reference.	Monthly production in viss @ lbs. 3·65.
1795	Colonel Symes	4,635,900
1797	Captain Cox	4,745,000
1826	Mr. Crawfurd	1,464,000
1835	Captain Hannay	4,743,000
1838	Captain McLeod	117,120
1855	Dr. Oldham	900,000
1855	Do. different estimate	375,000
1855	Captain Yule	596,000
1873	Captain Strover	500,000
1879–81	Burmese Minister	400,000
1886	Dr. Romanis	600,000
1886	Sir Charles Bernard	500,000

If we assume all these figures to be correct, the production must have largely fallen off since the end of the last century, but we will at once see that the large output of 4·7 millions of viss per mensem, is based on erroneous suppositions. On page 178 I pointed out that the number of wells at the end of the last century was probably not more than 130, of which 70 were productive wells. Supposing there were 100 and Captain Cox's estimate of 300 viss per day to be correct, the approximate monthly output would not be more than 9 lakhs of viss. But I think that even this reduced estimate is much too high, as I doubt whether there was such a large consumption of crude oil in the last century as to absorb a monthly output of 9 lakhs of viss, considering that during the last five years the local consumption (including India and Shan States) of crude oil amounted to not more than 1 lakh of viss. If we assume that before the influx of American oil the local consumption amounted to 3 or 4 lakhs of viss per mensem it is not easy to see what could have become of the surplus of 5 to 6 lakhs of viss. But even supposing the estimate of 9 lakhs per month to be correct, we can at once dispose of the statements of Mr. Crawfurd and Captain Hannay as being too high, and that of Captain McLeod as being undoubtedly too low.

We now come to the estimates of the members of Yule's Mission to Ava. They furnish three estimates ranging from $3\frac{3}{4}$ lakhs of viss up to 9 lakhs of viss per mensem. It remains to examine which of the three statements is to be considered as the most reliable. Dr. Oldham arrives at the lower estimate judging from the number of carts engaged in the oil trade, and by supposing the average load of each cart to be 100 viss. I will not argue about the number of cart-loads, supposed to be 150 per day, but the estimate of 100 viss per cart-load is undoubtedly much below the mark. Each cart now carries 12 pots, containing at least 12 viss of oil, that is to say, $12 \times 12 = 144$, say 150 viss.

We know, that in the oil fields nearly everything has remained in the same condition as it was a hundred years ago, and it is quite fair to suppose that the quantity of oil carried by one cart is the same now as it was in 1855. Dr. Oldham's second estimate must therefore be raised by half of its amount, if it is to come near the truth, and this will give an annual production of 57·5 lakhs of viss or 562,500 viss per mensem. It is then beyond doubt that Dr. Oldham's second estimate is too low.

On the other hand, in his first estimate he assumes the daily average production per well to be 180 viss. I dare say that this is rather too high an average, and I therefore think his final result to be too high.

Major Phayre arrives at his estimate in rather a remarkable way. He assumes the average yield per well in the Beme oil field to be 40 viss per day, in the Twingon area to be 230 viss. From all I know the estimate for Beme is undoubtedly too low, that of Twingon too high, but the two mistakes have apparently compensated each other and so Major Phayre's estimate of 5·96 lakhs of viss per month is very near the mark as it agrees well with the amount arrived at by correcting Dr. Oldham's second estimate. If we therefore suppose that the monthly output in 1855 amounted to about 6 lakhs of viss, we shall certainly rather be above than below the mark.

Not much can be said about other estimates. Captain Strover very likely gives the actual output during the year referred to. During the following years the production must have fallen off because, as we shall presently see by estimates arrived at by a different method, the statement of the Burmese Minister as to the output of 4 lakhs of viss which dwindled down to about 3½ lakhs of viss is corroborated.

B.—Period 1886 to the end of 1894.

Since the annexation of Upper Burma, careful records have been kept of the monthly production; of course they were interrupted in 1886 when owing to the disturbed state of the country, all work at the oil fields was stopped, and we find therefore that for this year the amount of production is only returned for seven months. Another pause happened in April 1887, but ever since the work has been steadily going on, as will be shown by the figures of the following table :—

Table showing the monthly production of the Yenangyoung native reserves from 1886 to 1894 in viss at 3·65 lbs.

	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.
January . .	...	588,520	489,380	503,240	557,430	403,150	521,755	697,210	755,300
February . .	...	516,470	416,150	518,570	501,800	454,570	395,880	693,585	665,950
March . .	...	369,820	488,550	537,770	569,180	571,100	352,520	838,530	804,283
April . . .	407,060	...	520,700	528,870	550,270	77,090	234,215	769,970	735,100
May . .	532,120	601,390	539,750	540,900	533,260	608,600	505,630	629,510	836,700
June . . .	462,510	586,260	530,290	551,040	608,130	928,290	551,640	765,500	801,350
July . . .	370,520	522,050	534,170	525,130	661,210	712,330	723,050	816,490	822,800
August . .	657,090	494,650	535,070	542,960	579,450	572,635	811,315	802,750	811,180
September . .	422,660	494,720	523,730	532,210	627,960	570,650	816,405	724,920	790,540
October . .	...	502,910	516,000	548,770	608,500	631,200	725,185	634,940	813,360
November . .	...	503,740	519,260	539,500	567,500	638,960	725,695	793,000	778,120
December . .	506,130	470,670	512,360	539,690	387,740	635,221	718,750	750,490	844,880
TOTAL .	3,418,090	5,651,200	6,125,410	6,408,650	6,761,430	6,803,796	7,082,040	8,917,895	9.459,563
Average per month	488,415	513,745	510,450	534,054	563,452	566,983	590,170	743,158	788,297

Although this table explains itself a few words may be said regarding the extraordinary low production in April 1891. This is solely due to the disorganisation of the oil trade which immediately followed the termination of the agreement made in March 1886 between the native well owners and the Burma Oil Company; the natives refused to sell their produce expecting to obtain a higher price for it, but as by that time the Burma Oil Company was independent of the supply from the native wells, the opposition soon broke down as the well owners found no buyers for their oil, and in the following month work was resumed in the ordinary way.

We may observe from the figures in this table that the average monthly output has been steadily increasing since 1886; it amounted in—

1886 to	. . . . . .	4·88 lakhs of viss.
1887 ,,	. . . . . .	5·13 ,, ,, ,,
1888 ,,	. . . . . .	5·10 ,, ,, ,,
1889 ,,	. . . . . .	5·34 ,, ,, ,,
1890 ,,	. . . . . .	5·63 ,, ,, ,,
1891 ,,	. . . . . .	5·66 ,, ,, ,,
1892 ,,	. . . . . .	5·90 ,, ,, ,,
1893 ,,	. . . . . .	7·43 ,, ,, ,,
1894 ,,	. . . . . .	7·88 ,, ,, ,,

The increase was very slow up to the end of 1892, but during the following year a sudden rise took place, increasing the production by 1½ lakhs of viss. As we know that in that year the number of productive wells had not much increased we must attribute this rise chiefly to the deepening of the wells which were thus rendered more profitable. A small rise, amounting to a little less than 1 lakh of viss, was noticed in 1894, but this can be attributed with great certainty to the new wells dug between 1893 and 1894.

Section V.—The Drilled Wells.

Although boring for oil in Upper Burma was started as early as 1887, it cannot be said that during the following year the progress of operations had been either rapid or extensive. Kodoung, between the Twingon and Beme area, had been selected for the operations, and up to end of 1888 only two borings were made, one of which hardly yielded any oil. Matters seemed very little encouraging, but the Burma Oil Company, which had undertaken the borings held on, and eventually success awarded their exertions.

The year 1889 marks an epoch in the history of the Yenangyoung oil field, because it is in this year that the number of borings at Kodoung quickly increased.

In the following year the Burma oil syndicate started boring operations south of the Beme tract, in blocks 1 S. and 2 S., they were, however, not awarded the success they deserved, none of the holes produced even a trace of petroleum, although considerable quantities of gas emanated from the borings situated close to the Beme tract. The syndicate eventually gave up the operations, tools and plant were sold, and this chapter in the history of the Yenangyoung oil field may be considered as closed.

The Burma Oil Company had in the meantime not been idle, and the land north of the Twingon area was tested where some oil was found in blocks 1 and 2 N.

I may here mention that two systems of drilling were used in the construction of bore holes. The Burma Oil Company first used the rod, but eventually changed for rope drilling. The bores of the Burma oil syndicate were throughout drilled with the rod. Without going further into the details of the two systems, it may be interesting to say a few words as to which system apparently proved more advantageous in the Yenangyoung oil field. There is no doubt that the cable system has the great advantage of quickness, which is the more apparent the deeper the bore is. On the other hand the rod system has the advantage of rigidity and weight, which enables it to force its way when the cable fails to do so. It seems that when strata like the clay (*e* p. 94) which caves very badly, have to be repeatedly drilled through, the cable system works quicker and is therefore more economical up to a depth of about 400 feet from the surface. Deeper holes have only been drilled under the greatest difficulties with the cable, while the rod by sheer weight forced its way in a comparatively short time through the caving masses found between 800 and 1,100 feet.

However the case may be, the question of the personal equation must not be entirely disregarded and a workman accustomed to drill with the rope, might fail with the rod, because he looks at the latter as a very inferior system. *Mutatis mutandis* the same holds good for a driller who only knows the rod drilling system.

Without deciding the question which system would be the most economical for Burma, I may offer one caution, which will apply to either case, and this is, that the first rig intended for test boring only should be as light as possible. Access to those localities which will have to be tested in future, is extremely difficult, if not altogether impossible, for heavy machinery. There are no roads worth speaking of, except such as may be passed by mules, and even such parts as are comparatively close to the river, like the northern continuation of the Yenangyoung anticline, are so absolutely destitute of water that the question of water supply for the boiler would involve either enormous expense, or would cripple the experiment before it has actually been started.

Number and depth of drilled wells.—Although the first drilled well was not commenced earlier than 1887, there is already some difficulty in ascertaining the total number of wells drilled. Some of them were dry holes, therefore abandoned, and no further traces can be discovered of their location ; there are at least five of these wells, to which has been recently added a sixth one, the location of which however is known and the boring record is preserved. Of the others the location and boring record of the pioneer well, so to speak, is known to me, although it is entirely abandoned now ; I gave this well the distinguishing letter A ; two more wells were drilled, if I am not mistaken in 1888, both of which have been abandoned ; another couple of dry holes were drilled in 1889, their location is unknown, as well as the record of the strata met with ; another well was drilled inside one of the pit wells (Government well No. 131) ; it hardly yielded any oil and the piping was withdrawn and boring register unknown. Well No. 64 yielded no oil, luckily its position and boring register, which is extremely valuable from a geological point of view, have been preserved ; but the rig has been removed and another No. 64 has been just finished west of well No. 21 ; I numbered it No. 64A.

The Minlindoung wells drilled by the Burma oil syndicate, 1890 to 1892, in blocks S. 1 and S. 2 south of Beme have been abandoned, and their traces will be entirely obliterated after another rainy season. There are therefore at least 14 drilled wells which have entirely disappeared, and if of the majority the boring record and location is known, some of them have left no traces behind. As there are at present (February 1895) 67 wells in working order, the total number of drilled wells cannot therefore have been less than 80.

These 80 wells are distributed over the area of the Yenangyoung oil field in the following manner :—

70 were drilled at the central part of the field, Kodoung.
2 (No. 44 and 45) were drilled in blocks N. 1 and N. 2, north of the Twingon reserve.
1 (No. 68) was drilled west of the Twingon reserve.
7 (Nos. I to VII) were drilled in block S. 1 and S. 2, and south of the Beme reserve.

The greatest depth reached was 1,011 feet from the surface ; this bore has, however, been abandoned as it yielded no oil. But by far the majority of wells have only reached a depth of between 300 and 400 feet from the surface ; they are therefore comparatively shallow wells.

2. *Production of the drilled wells.*—As this is the most important feature, I tried to secure as much reliable information as possible in this matter, but unfortunately those things which are of importance to the scientific observer are not always of the same interest to the practical man. His sole aim is a high production, and to get this as quick as possible his chief interest ; but still features in the production have been ascertained which are worth mentioning.

The highest daily production of one well hitherto observed, was 13,000 viss or nearly 130 barrels of 42 gallons. This may be a large yield for Burma, but it is insignificant with that observed at the wells of Baku or the United States.

It has also been observed that the yield of a freshly drilled well is very considerable during the first few days, it then generally falls rapidly off for a short time and eventually settles down to a certain quantity, which it keeps for years. The remarkable feature is that some wells, although they have steadily produced oil for at least six years, have shown no signs of exhaustion yet.

The following table will show the monthly production of the drilled wells in the Yenangyoung oil field :—

Production of the drilled wells in the Yenangyoung oil field for the years 1888 to 1894.

	1888.	1889.	1890.	1891.	1892.	1893.	1894.
January	1,560	7,160	116,170	70,650	886,000	586,740	1,029,373
February	6,670	5,800	101,630	50,890	678,900	822,260	994,058
March	9,000	5,500	226,330	8,010	637,400	1,026,860	1,116,332
April	2,520	19,670	282,260	569,590	1,041,900	1,468,925	1,005,849
May	4,560	21,090	257,860	709,330	1,732,500	1,513,869	829,621
June	3,320	12,000	345,170	655,380	1,636,330	1,493,196	659,918
July	...	6,870	460,460	905,610	1,366,920	1,811,361	1,729,147
August	...	26,090	509,580	862,290	759,770	1,815,496	1,577,041
September	...	20,490	437,650	823,500	1,187,950	1,334,634	1,186,954
October	5,060	26,060	478,480	818,500	1,306,220	963,787	1,832,342
November	8,900	142,690	387,210	837,000	755,120	1,342,382	1,790,578
December	...	133,710	68,280	559,300	924,530	526,829	1,718,299
TOTAL	41,590	427,130	3,671,080	6,870,500	12,913,540	14,706,279	15,469,512

The chief interest of the above statement rests in the, comparatively speaking, large increase of the production within a few years. During the year 1888, the insignificant quantity of 415 barrels only was produced; in the same year the pit wells yielded 61,254 barrels, that is to say, over 147 times the quantity; it cannot be said that this was a very encouraging start, after the large expectations, although it must not be forgotten, that there were only two, at most three, drilled wells in 1888, but unfortunately these were constructed in the poorer region of the field.

However, undaunted by this disappointment, the company went on, and the production at first rose slowly, but with the increased number of wells, quicker, till in 1891 with 68,705 barrels, it has not only reached the production of the pit wells, but exceeds it by a trifle, the latter being 68,037 barrels.

From that time the drilled wells had the upper hand, because from 1891 to 1892 the production rose from 68,705 to 129,135 barrels, that is to say, an increase of about 88 per cent. The next two years show again only a slight increase, 1894 closing with a production of 154,695 barrels, that is to say, exactly $1\frac{1}{2}$ times the production of the pit wells which amounted to 94,595 barrels during the same year.

It is certainly by no means a bad progress that within seven years the production of the drilled wells has increased to such an extent, that from being $\frac{1}{147}$ of the production of the pit wells at the end of the first year, it amounts to $1\frac{1}{2}$ times that production at the end of the seventh year, although this same production has more than doubled during the same period.

If anything can prove the superiority of the drilled wells over the dug pit wells, these figures should do so. It may perhaps be argued that the drilled wells have been constructed in a richer region of the oil tract, but so far as my experience goes, this is by no means the case, if anything, the Twingon area is decidedly the richer portion of the two, the 1st and 2nd sand being petroliferous, while they are dry at Kodoung.

Section 6.—Summary of the production of the Yenangyoung oil field.

In the following table is given the production of the Yenangyoung oil field for the last nine years :—

	Production in viss.
1886	3,418,090
1887	5,651,200
1888	6,167,000
1889	6,835,780
1890	10,432,510
1891	13,674,296
1892	19,995,580
1893	23,624,174
1894	24,929,075

In themselves the above figures show a highly satisfactory progress; within nine years the production has risen from 34,180 barrels to 249,290 barrels, that is to say, an increase of nearly 800 per cent. If a similar increase were to be expected during the next nine years matters would look more promising, but as I have pointed out previously (page 123) it is more than doubtful whether a similar rise may be expected. A comparison of the production of Upper Burma with that of other countries will be postponed till the Yenangyat oil field has been discussed.

Chapter II.—THE YENANGYAT OILFIELD.

Section I.—The Pit wells.

A.—Period previous to 1887.

As already mentioned (see page 124) the surface indications of the existence of an oil bearing sand near the hamlet of Yenangyat were noticed by previous visitors, as Mr. Crawfurd and Dr. Oldham, but it is almost certain that no exploitation of this part took place until a very recent period ; there were certainly no wells in existence when the members of the Mission to Ava visited Yenangyat in 1855, and the statement that the first wells were constructed in 1864 is highly probable, although it seems quite likely that they are even younger.

According to Burmese statements these were constructed in the Burmese years:—

1216* to 1220	30 wells.
1221 to 1225	50 „
1226 to 1230	20 „
1233	5 „
1235 to 1239	29 „
TOTAL	168 „.

The first authentic information about the Yenangyat oil field has been given in Captain Strover's report, who states that in 1873 there were 50 wells at Yenangyat. Unfortunately he does not say whether this number includes the unproductive wells, or not.

In the following year Dr. Friedländer visited the Yenangyat oil field, and he gives the number of wells as 70. Dr. Friedländer's statements are, however, very unreliable, and not much value can be attached to his figures. If the data supplied by the natives are correct, then there must have been at least 139 wells in existence in 1873, the Burmese year 1233—1234 corresponding to A.D. 1873. It is therefore probable that Captain Strover's, as well Dr. Friedländer's statements, refer to the productive wells only. No information has been obtained regarding the production, which to judge from our present experience can never have been large.

B.—Period 1887 to 1894.

My first visit to the Yenangyat oil field took place in June 1891, when a survey was arranged, and the wells carefully counted. Records of the monthly production have, however, been kept, although in a somewhat careless way, since the beginning of 1887. The wells, of which there are altogether 138, are situated in three different valleys, north of the village of Yenangyat. Among them there are —

Productive wells	18
Unproductive wells	120

* The Burmese year 1216 corresponds to A.D. 1864.

A. *Productive wells.*—The productive wells have never attained any depth worth speaking, there are in the—

I class, below 150 feet	. . . .	14 wells
II „ from 150 to 200 feet	. . .	4 „

a proportion which has not changed since. With regard to their daily production, these belonged to the—

1 class yielding less than 21 viss	. .	12 wells.
2 „ „ from 21 to 50 viss	. .	6 „

We see, therefore, that the Yenangyat wells are very poor even for Burma. With regard to the relation between depth and production, we observe that the wells of the first class yield a total daily production of 213 viss, while those of the second class produce only 76 viss. As it has been proved by the deep borings that all the productive wells draw their oil from one and the same petroliferous sand, no importance need be attached to the above portion.

(*b*) *Unproductive wells.*—The unproductive wells are all abandoned wells in all states of dilapidation; it is stated that most of them never produced oil, a statement which I fully believe. There are however no wells under construction, nor is there a struggle for well sites observable. In fact the Yenangyat oil field gives the impression that the work is only casually performed, but as the oil is a light one, it is very much appreciated.

Production.—The following table will show the monthly production of the pit wells in the Yenangyat oil field:—

Production of the pit wells in the Yenangyat oil field for the years 1887 to 1894.

	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.
January . . .	5,000	11,000	7,500	8,700	8,200	10,000	9,900	11,240
February . .	5,800	9,500	8,000	8,700	8,200	10,000	9,300	10,460
March . . .	7,200	9,500	8,000	9,000	9,000	10,000	10,000	11,020
April . . .	...	9,500	9,500	9,000	6,200	10,800	10,300	11,160
May . . .	10,000	9,500	9,800	9,000	6,000	10,800	9,600	10,820
June . . .	11,000	9,500	9,500	9,000	11,200	10,800	10,800	10,460
July . . .	11,000	9,000	9,500	9,000	12,000	10,800	10,600	10,680
August . . .	10,500	8,500	8,800	9,300	11,500	10,400	8,960	10,740
September . .	9,010	8,000	9,500	9,300	10,500	9,000	9,000	10,340
October . .	7,000	7,600	8,000	8,700	10,700	11,200	8,100	10,640
November . .	6,000	7,000	8,500	8,000	10,500	9,400	9,980	8,720
December . .	7,500	7,500	8,500	8,200	10,000	10,100	11,520	9,580
TOTAL .	90,010	105,100	105,100	105,900	114,000	123,300	108,060	125,860

(254)

The chief feature of these figures is their insignificance, the largest annual production, ever on record, being 1,258 barrels, that is to say, the Yenangyat oil field produces as much in one year as the pit wells of the Yenangyoung oil field produce in about 4 days.

SECTION II.—THE DRILLED WELLS.

Since the summer of 1891 a few wells have been drilled in the Yenangyat oil field, but it cannot be said that they have proved a success. However, we must reserve our judgment regarding the importance of the Yenangyat oil field, till a few more test wells have been constructed. There are at present 7 wells, which are all situated in the Yenangyoung ravine. Of these 6 are productive; one did not yield oil and was abandoned. The wells are generally much deeper than those of Yenangyoung, without however the object of a good production having been attained.

Like the pit wells, the drilled wells are very poor, even much more so than the former. I have no accurate data regarding the individual daily production of these wells, but it is certain that it never could have exceeded 210 gallons per day; most probably it ranged from 126 to 168 gallons. If compared with the wells of the Yenangyoung oil field, where a well yielding 500 gallons is considered to be a poor well, the above production must appear very insignificant, and can hardly be considered as a great inducement to further efforts.

The following table will show the monthly production, as recorded during the last two years :—

Year.	1893.	1894.
January	...	54,053
February	...	45,476
March	...	44,363
Carried over .	...	143,892

Year.	1893.	1894.
Brought forward .	...	143,892
April	27,229	44,099
May	30,108	65,945
June	25,858	61,886
July	16,391	58,523
August	21,350	59,500
September	25,989	59,170
October	35,726	60,511
November	37,396	58,663
December	51,880	63,196
Total .	281,927	674,085

This table does not call for any special remarks, except that, comparatively speaking, the large increase of the production within one year is solely due to the increased number of wells.

Chapter III.—THE PETROLEUM PRODUCTION OF BURMA.

Having in the previous chapters discussed the production of the two oil fields which were exploited in Burma, up to the beginning of 1895 as well as the means by which this production is obtained, there remains only to consider Burma generally as an oil producing country. I refrain from expressing my views for the period previous to 1878-79, as the data available are more or less unreliable.

We are, however, able to check the statements regarding the production since 1878-79, from the returns of the import of crude oil into Burma during the financial year 1878-79 to 1885-86. There being only one highway by which the oil could be transported to Burma, namely the Irawadi, the figures about the quantity of the imported oil may be considered accurate, provided the records were properly kept. We also know that previous to the influx of kerosine oil from America, about one third of the total production of Burmese oil was consumed in the country and are, therefore, justified in estimating with tolerable accuracy the total production from the amount of imported oil.

Table showing the production of the oil-fields of Burma.

Financial Year.	Viss.	Remarks.
1878-79 . .	1,916,769	Estimated: the year being one of political disturbance it is rather doubtful whether these figures even approximately represent the actual output; it is more likely that they are below the mark.
1879-80 . .	3,724,128	Estimated. The estimate is based on the statement of a late Burmese minister, that about 15·6 lakhs of viss: or 32·5 per cent. of the annual production were consumed in Upper Burma; the rest was exported to Lower Burma. The import of crude oil was registered at Thayetmyo, and this quantity was accordingly estimated at 67·5 per cent. of the total production. The production of Yenangyat is estimated at viss 100,000.
1880-81 . .	4,434,865	
1881-82 . .	3,416,234	Estimated, see note above. The import has, however, decreased, and it only amounts to 61·5 per cent. of the total production. It is supposed that during these three years the proportion between consumption in Upper Burma and export into Lower Burma did not change. Production of Yenangyat as before.
1882-83 . .	4,221,630	
1883-84 . .	3,980,528	
1884-85 . .	4,577,556	Estimated, if however the same proportion of consumption and import (38·5 : 61·5) were used for the calculation of the production, the result 62 and 63 lakhs of viss per annum would apparently be too high. The ratio of imported oil must therefore be necessarily higher, and it is supposed that it is the same as in 1886-87, namely, 82·2 per cent. of the total production; this may be too much, and the actual production is therefore rather higher than the estimate. Production of Yenangyat as before.
1885-86 . .	4,528,667	

The above figures seem to prove that there was no great fluctuation in the production of oil previous to 1886, the production seems to have sometimes fallen, sometimes risen, but it has apparently never exceeded 45,000 barrels per year.

In the following table the production is given for the calendar years 1886 to 1894—

	Barrels.
1886	34,180
1887	57,412
1888	62,721
1889	69,408
1890	105,384
1891	137,882
1892	201,188
1893	240,141
1894	257,290

As already stated the above figures mark an enormous rate of progress within these few years, but what are after all 257,290 barrels compared with the production of Baku or America?

For comparison I give below the figures of the production of the two most important centres, as far as I have been able to obtain them. The figures for America are extracted from Stawill's[1] valuable book, and those for Baku from Erdmann's[2] interesting paper:—

	America.*	Baku.*
1886	28,064,841	17,857,142
1887	28,278,866	19,642,857
1888	27,612,025	22,797,738
1889	35,163,513	24,285,714
1890	45,822,672	28,928,521
1891	54,291,980	Unknown.
1892	50,509,136	...
1893	48,412,666	...

[1] Mineral resources of the United States, 1893, p. 8.

[2] Das. Kaukasische Erdöl, Zeitschr. für Naturwissensch. Ap., LXV, 1892.

* Production in barrels 42 imp. gallons.

We see that in the face of the above figures the production of Burma of a little over a quarter million of barrels is very insignificant. Even Galicia and Roumania exceed Burma in quantity; according to Höfer,[1] the production of Galicia amounted to 571,538 barrels as far back as 1886, of Roumania 269,230 barrels in 1881.[2]

The present production of Burma about equals that of Canada in 1886, the latter being on the fifth or sixth rank as a petroleum producing country, and so far as is known to me Burma exceeds only a few countries, where the production of petroleum is of very minor importance. So far the dreams cherished by some, have not been realized as regards the petroleum production of Upper Burma, although the most important field has been thoroughly tested. Whether the future will bring a change remains to be seen, but I believe this to be highly doubtful.

Chapter IV.—THE COST PRICE AND THE TRADE VALUE OF THE BURMESE PETROLEUM.

The trade value of the Burmese petroleum seems to have undergone various fluctuations at different times. If Colonel Symes' statement is correct the value of the oil must have been trifling near the end of the last century, as 200 or 300 pots were sold for one tical = R 1-4-0. I am inclined, however, to think that he must have been misinformed, because Captain Cox states that 100 viss were sold for $1\frac{1}{4}$ tical, say R 1-10-0. As 200 or 300 pots contain at the lowest estimate, 2,000 or 3,000 viss, 100 viss would have been sold for less than 1 anna, which is so trifling a sum that it would have been entirely insufficient to pay for labour alone. For this reason I think Colonel Symes' statement to be erroneous and Captain Cox' figure nearer the truth.

There is no further information about the value of the petroleum till 1835, when Captain Hannay estimates its value at about R3 per 100 viss.

In 1855 Captain Yule stated that the ordinary price of the article

[1] Höfer, Erdöl, p. 152.
[2] *Ibid.*

used to be one tical per 100 viss, but that lately, in consequence of the demand from Rangoon, it had risen; at the price given of 15*s.* per ton, the price of 100 viss must have been something like R1-8. This estimate agrees very well with Captain Yule's statement of the value of the oil imported into Lower Burma in 1855, stated to be R21,972, which answers to a rate of about R1-4·0 per 100 viss.

The year following the visit of the members of the Mission to Ava marks a new epoch in the history of the Yenangyoung oil field; the extraction of oil was declared a Royal monopoly.

Hitherto the well owners enjoyed the full benefit of the sale of their oil, but from this time on they were bound to make it over to the king at the fixed rate of R1-8-0 per 100 viss. We are luckily in the position to fix the introduction of the monopoly system very accurately. It did not exist in 1855 when Captain Yule visited the oil fields, but in a foot note, he says "petroleum which has acquired a great additional value in consequence of the demand for the English market has recently been added to the Royal monopolies." As the narrative of the Mission to Ava was published in 1858 we must assume that the monopoly was introduced in 1856 or 1857. This supposition agrees perfectly with the native statement that in 1218 or 1219 of the Burmese era the king forced the well owners to sell him all their oil at the fixed rate of R1-8-0 per 100 viss.

It is hardly a mere accident that the introduction of the petroleum monopoly nearly coincides with the occupation of Lower Burma; we may even say it was a consequence of it. With the annexation of Lower Burma the demand for petroleum increased owing to the establishment of a larger export and with the increased demand the selling price naturally rose. The king quickly perceiving the advantage he would derive if the whole of the oil trade were in his hands, declared the oil to be one of the articles which, like rubies, were Royal property and could only be sold by the king or persons authorized by him. Whether there was a formal agreement with the well owners or not, is difficult to say. A Burman remarked philosophically, when I enquired about this subject that in those days they had simply to do what the king told them, and there was no remonstrating against his orders. With the monopoly the price of the oil rose considerably, I cannot ascertain whether at once to its later figure or only gradually ; from 1879 to 1891 the price was R25 per 100 viss brought up the river and R15 per 100 viss brought down the river. Afterwards the price for upcountry oil rose to R25, that for Lower Burma fell to R7 per 100 viss, but it subsequently recovered and till April 1891 the ordinary selling price of crude oil delivered at the river bank was R15. The local Government having given back the right of free sale to the native well owners the price of the crude oil dropped at once owing to the competition of the oil from the drilled wells and in May 1891 it sold for R2-12-0 per 100 viss delivered at the river bank.

The cost price of the oil is very low, and it seems that it has not changed for a good many years, but unfortunately no information may be obtained about this subject from previous accounts about the oilfields. Captain Cox states that four labourers were required to haul up the oil and that they received one sixth of the value of the oil drawn at the rate of 1¼ ticals per 100 viss. This would roughly amount to 4 annas per 100 viss ; cart hire seems to have been paid separately, as Captain Cox states that the value of the oil is increased to three eighths of its value at the oilfields, the price at the river bank being 2 ticals (R 2-8-0). Should this be correct, the actual cost price per 100 viss was originally low, but was considerably increased by the cost of cart hire, which was something like 15 annas per 100 viss.

In later years the actual cost price, including cart hire, was reduced to 8 annas per 100 viss. It was supposed, that the man who carted the oil down to the river, had to provide also the labour of hauling up the oil. This was generally done by members of his family, and he received 8 annas for every 100 viss of oil, under the obligation, however, that he was to cart the oil down to the river.

CHAPTER V.—THE PETROLEUM TRADE.

The subject treated of in this chapter cannot unfortunately be dealt with in so exhaustive a manner, as might be desirable, owing to the rather scanty information available.

It seems that up to the time of the annexation of Lower Burma in 1853, the bulk of the production of oil was consumed locally, that is to say, it was used for illuminating purposes to a small extent, but chiefly for preservation of the timber of boats, houses and monasteries. Small quantities may have been brought over to India; it is, however, quite certain, that a considerable quantity found its way through the Shan States into Western China. It is very difficult to arrive at a correct idea about the quantity thus consumed. At present the local consumption, including export to India, is something like a lakh of viss per mensem; in 1879 it amounted to about 1½ lakhs. If we assume that in former years the local consumption amounted to double this quantity, or 3 lakhs of viss per mensem, I believe we are very near a correct estimate.

After the occupation of Lower Burma there seems to have been a considerable export of crude petroleum to England. Captain Yule states, page 20: "There is now a considerable export of the article from Rangoon to England and one of the Rangoon houses had a European agent residing on the spot." According to the same authority lbs. 6,679,140 = viss 1,830,000 passed the custom house at Thayetmyo from 1st February to 1st November 1855 on their way to Rangoon. This would answer to an average monthly export of 228,750 viss; in round figures 2¼ lakhs of viss per month. Assuming that this quantity represented half the total production we arrive at an estimated monthly production of 4½ lakhs of viss, that is, pretty close to the same amount which I supposed to be the production in 1855. No more data are available concerning the import of crude oil into Lower Burma till 1880-81, although it is quite certain that all this time considerable quantities of crude oil were exported from Rangoon to Europe.

An enterprising firm, Messrs. Finlay, Fleming & Co., started a refinery at Rangoon, but it seems that up to 1886 the concern was not very profitable, owing most probably to the high price of the crude oil. After the annexation of Upper Burma a limited liability company under the name of the "Burma Oil Company" with a capital of £120,000 was formed which took over the stock and plant of the refinery, and owing to the lower rates at which the crude oil could now be obtained from the native well owners, business prospered.

This state of things prevailed until March 1891, when the five years' contract, which the firm had entered into with the native well owners, came to an end, and the latter, apparently tempted by the high price the petroleum had hitherto commanded (see page 215), refused to enter into a new contract on the previous terms.

In the meantime the Burma Oil Company had energetically pushed on the drilling of wells at Kodoung in the central part of the Yenangyoung oil field, and having succeeded in turning out a larger quantity of oil than was required to supply the refinery in Rangoon, was in the lucky position of being independent of the supply from the native wells.

The native well owners stubbornly refused to come to terms with the Company, hoping that they would now receive the R25 for which 100 viss of oil had hitherto been sold. But to their intense surprise the price of oil fell on the 1st of April 1891 to R2-12 per 100 viss, and they were subsequently only too glad, when another Company, the Yenangyoung Petroleum Company, Limited, offered to take the whole of their production at R4 per 100 viss. Anybody, however, who knew of the conditions of the production, could foretell with certainty, that this new undertaking could not possibly prosper, and after a life of hardly a year it failed, and matters stand now exactly as in April 1891, if not worse, for the native well owners.

I have now to deal with the various branches of the petroleum traffic, *viz.*, local consumption, import into Lower Burma and export from Rangoon.

SECTION 1.—THE LOCAL CONSUMPTION OF CRUDE OIL.

As already pointed out it is very difficult to form an opinion about the quantity of the local consumption previous to the annexation of Upper Burma. For the three years following the annexation we may form an estimate by deducting the oil exported into Lower Burma, from the total production, the quantity of both being known, the balance showing the probable local consumption. The figures thus obtained are, however, not as correct as one might wish because this quantity represents the offtake of a local contractor who having made an agreement with the Burma Oil Company, had secured the monopoly of supplying the whole of Burma and India with crude oil. The crude oil subsequently imported into Lower Burma and exported to India is included in the figures representing the import of crude oil into Lower Burma. The consumption of crude oil in Upper Burma, including oil exported to China, must therefore be smaller than represented by the following table.

In computing these figures I assumed that for the period 1880-81 to 1885-86 one third of the total production was consumed locally, basing this assumption on the statement of the Burmese Minister above referred to (page 27). For the years 1886-87 to 1890-91 the actuals being known the figures will represent the offtake of the local contractor, which includes oil subsequently imported to Lower Burma, part of which was exported to India.

From the 1st of April 1891, up to the present date, no accurate figures can be given, because the native well owners have obtained the right of free sale, the local consumption is supplied by countless channels, through which the oil finds its way from the producer to consumer.

Table showing the estimated local consumption of crude oil from 1880-81 to 1890-91.

Financial year.	Viss of 3·65 lbs.
1880-81	1,508,831
1881-82	1,376,750
1882-83	1,686,707
1883-84	1,594,003
1884-85	762,695
1885-86	755,442
1886-87	736,831
1887-88	1,420,743
1888-89	248,760
1889-90	1,742,662
1890-91	2,503,278

From the above figures we may assume that up to 1885 the local consumption was something like 1 lakh of viss per month; during the years following the annexation, it fell off greatly, being a little more than half a lakh of viss. If we consider that the oil is chiefly used for industrial, not for illuminating purposes, we understand that during the years of unrest which followed the annexation, the local consumption must necessarily decrease. From 1887 the above figures show strange fluctuations which cannot easily be explained. It is, however, certain that with the return of order in Upper Burma, the local consumption greatly increased, and it is certainly not far from the mark, if we estimate it at present between $2\frac{1}{2}-3$ lakhs of viss per mensem.

Section 2.—Import of crude oil from Upper into Lower Burma.

The oil fields at present exploited in Upper Burma being situated on the banks of the Irawadi, there is only one way by which the petroleum can be transported to Lower Burma and thence to Europe, which is at the same time the shortest and cheapest, *viz.*, the river itself. Accurate statistics of the quantity carried down the river would thus be of double value; if compared with the figures representing the export of petroleum from Rangoon, it would permit a very fair estimate to be made as to the quantity of petroleum, consumed in the country in addition to that quantity of crude oil which has been consumed locally. The latter quantity could easily be obtained by deducting the quantity of oil imported into Lower Burma from the total production.

The following table will show the import of crude oil into Lower Burma for the period 1880-81 to 1888-89, as registered in the custom house at Thayetmyo; unfortunately since 1889 the import traffic was no longer registered at Thayetmyo, the figures for 1889-90 and 1890-91 are therefore estimates only, which are probably too low in the former and too high in the latter year; since 1890, the petroleum imported into Lower Burma was again registered at Thayetmyo, and the years following 1891 give therefore the actuals again. Up to 1888-89 the custom house returns show the quantities in maunds at 82·28 lbs., from 1891-92 in gallons. I give the actual figures as obtained from the Custom-house authorities which I have converted into viss—

Financial Year.	In maunds at lbs 82·28.	In viss at lbs 3·65.
1880-81	129,801	2,926,034
1881-82	90,473	2,039,484
1882-83	112,451	2,534,923
1883-84	105,868	2,386,525
1884-85	169,230	3,814,861
1885-86	167,383	3,773,225
1886-87	188,372	4,246,369
1887-88	189,197	4,264,967
1888-89	274,352	6,184,570
1889-90	No record.	5,499,598*
1890-91	No record.	9,074,343*
	Gallons.	
1891-92	3,587,419	8,541,500
1892-93	5,360,119	12,762,200
1893-94	7,331,483	17,455,900

If Captain Yule's statement regarding the quantity of petroleum imported into Lower Burma is correct, there seems to be hardly an increase noticeable up to 1884. The import into Lower Burma would therefore have remained stationary for a considerable number of years, special fluctuations of course always excluded. This view is in some way supported by the returns for the period 1880 to 1884 which show only small fluctuations.

From 1884 the import rose steadily, till in 1889 it had treble the quantity of 1882, or within seven years an increase of about 300 per cent. in the quantity of petroleum transported to Lower Burma took place. Since that year the import has steadily risen, but during the last two years it jumped to the unprecedented height of 17,455,900 viss, that is to say, an increase of 600 per cent., as compared with 1880-81 is noted.

SECTION 3.—EXPORT OF PETROLEUM AND ITS PRODUCTS FROM RANGOON.

"Rangoon oil" has been known a good many years and has obtained a high reputation as a lubricant throughout the world, and it appears that the demand for it was always greater than the supply.

The following table will show the export of mineral oil, including crude oil, refined petroleum, and paraffine wax, obtained as a waste-product in refining the crude oil. As all the petroleum destined for export (except such small quantities as go overland to China), has to pass Rangoon, the subjoined table will show the total foreign trade in petroleum from Burma.

Table showing the export of Burmese petroleum and other products derived therefrom, from Rangoon, during the period 1880-81 to 1893-94.

FINANCIAL YEAR.	EXPORT OF MINERAL OIL (CRUDE AND REFINED).	EXPORT OF PARAFFINE WAX.
	Gallons at lbs. 8·83.	Cwts.
1880-81	217,625	*Nil.*
1881-82	237,440	13
1882-83	363,490	*Nil.*

Financial Year.	Export of mineral oil (crude and refined).	Export of paraffine wax.
	Gallons at lbs. 8·83.	Cwt.
1883-84	355,529	*Nil.*
1884-85	495,763	321
1885-86	547,200	3,825
1886-87	492,269	4,339
1887-88	626,216	5,757
1888-89	716,849	6,038
1889-90	921,397	7,920
1890-91	828,429	8,485
1891-92	1,189,098	13,635
1892-93	1,335,506	21,278
1893-94	1,522,981	28,858

This table shows that foreign traffic in petroleum has steadily increased, having risen from a little over 5,000 barrels in 1880-81 to 22,250 barrels in 1889-90, that is to say, an increase of over 300 per cent. during nine years. If we consider that during the same period the import of crude oil into Lower Burma had risen only about 100 per cent. it follows that there must have been an increasing demand for Rangoon oil, etc., which had to be complied with at the expense of local consumption, a fact that will be further proved by the next table.

During late years the export still rose, and the latest returns for 1893-94 with 38,166 barrels show an increase of 626 per cent. over those of 1880-81. Although in themselves highly satisfactory, those figures prove, however, how really insignificant the foreign trade in Burmese petroleum is as compared with that of America or Baku. There is no doubt that the export is still capable of expansion, but even if it double, the quantity of, say, 80,000 barrels would have not the slightest effect on the petroleum market of the world. The only effect would perhaps be, to lower its own selling price. Unless much richer fields are discovered, of which, however, there is hardly any probability, the trade in Rangoon oil will remain in its present modest, though profitable, position.

An interesting feature in the above table is the enormous increase of the export of paraffine wax during the period 1884-85 to 1893-94, probably due to more improved methods of manufacture.

The figures show some further interesting facts regarding the petroleum trade of Burma. As the total production of crude oil is known, as well as the imports of the same into Lower Burma, and the exports therefrom in the shape of crude and refined oil, and paraffine wax, it is easy to calculate the proportion these branches of the trade form to the total production. These figures will be found in the following table, in per cents. of the total production of crude oil.

Financial Year.	Import of crude oil into Lower Burma.	Export of mineral oil from Rangoon.	Total export of mineral oil and paraffine wax from Rangoon.
1880-81	67·5**	11·8*	11·8**
1881-82	61·5*	16·7*	16·7**
1882-83	61·5*	20·8*	20·8*
1883-84	61·5*	21·5*	21·5**
1884-85	85·2***	26·1*	26·3
1885-86	85·2***	26·7*	29·3
1886-87	85·2	23·9	26·5
1887-88	75·0	26·7	29·8
1888-89	96·1	26·9	29·8
1889-90	75·9*	30·7	34·0
1890-91	90·5***	19·6	22·4
1891-92	54·3	18·0	20·7
1892-93	59·4	14·9	18·0
1893-94	70·2	14·1	18·1

* Estimate. ** No export of paraffine wax. *** Probably too high.

As regards the proportion which the import of crude oil into Lower Burma bears to the total production, we see that it has undergone the greatest fluctuations. From 96 per cent. in 1888-89 it has fallen to as low 54·3 per cent.; that is to say, while in the former year nearly the whole of the output was imported into Lower Burma, in the latter only a trifle over half of the production went to Rangoon. Since that time it has again risen, but amounts to less than three quarters of the total production. It is very difficult to explain these fluctuations; in former years the balance not exported to Lower Burma was certainly consumed locally, that is to say, it was shipped up the river or carted inland and used for the various purposes to which the natives apply the crude oil.

At present the balance not shipped to Rangoon, by no means represents the local consumption, a certain quantity always remains in the storage tanks. During the last two calendar years the local consumption was more than 9 per cent. for 1893, and 6 per cent. for 1894, of the total production; but even if we add another 10 per cent. to the local consumption, and allow 10 per cent. for leakage and what is by no means an unimportant factor in this hot climate, evaporation during the transport to Rangoon, the large deficiency in some of the figures cannot be explained.

Another remarkable feature is demonstrated by the figures representing the export of mineral oil and its products from Rangoon. It is unquestionable that the proportion, which the exported oil forms of the total production, has been steadily rising till 1889-90, when it amounted to a trifle over one third of the total. Since that year it has been rapidly falling, till during the last two years it amounted to not more than 15 per cent. It is evident that there must be an explanation for this remarkable decline, and in order to find this out, I computed the following table which shows the proportion the exported oil and its products bear to the quantity of oil imported into Lower Burma is expressed in percentages.

Financial Year.	Export of mineral oil from Rangoon.	Export of mineral oil and paraffine wax from Rangoon.	Balance probably representing local consumption.
1880-81	18·0	18·0*	82
1881-82	28·1	28·1*	71·9
1882-83	34·6	34·6*	65·4
1883-84	36·0	36·0*	74
1884-85	31·1	31·6	68·4
1885-86	32·1	34·1	65·9
1886-87	28·0	31·1	68·9
1887-88	35·5	39·7	60·3
1888-89	28·0	31·0	69·0
1889-90	No record.		
1890-91	No record.		
1891-92	33·1	38·1	61·9
1892-93	25·0	30·0	70·0
1893-94	20·7	25·8	74·2

* No export of paraffine wax.

The table proves clearly that only a small percentage of the total quantity of crude oil is again exported from Rangoon, in any shape, either crude or refined. During the last financial year this quantity amounted just to one fourth of the quantity of the imported oil.

The balance must find its way somewhere, and most naturally the idea almost suggests itself, that the oil is consumed in the country chiefly in the shape of illuminating oil. This view is strongly supported, when we examine the import of foreign mineral oil into

Burma. This was imported to the following extent during the years noted :—

Financial Year.	Gallons.
1890-91	2,239,955
1891-92	2,453,108
1892-93	3,082,795
1893-94	1,738,743

These figures prove that up to 1892-93 the import of foreign oil steadily increased, but in 1893-94 it fell to the extent of almost 50 per cent. It is probably safe to assert, that this decrease is due to the increased local consumption of refined Burmese oil. We know that in 1893-94, 7·2 per cent., say, 75 per cent. of the imported oil or about 5½ millions of gallons, must have been consumed locally. If we suppose that from 40 per cent. to 50 per cent. of this quantity[1] has been converted into illuminating oil, the above would represent about 2¼ to 2¾ millions of gallons of illuminating oil, which represents about the figure by which the foreign oil imports have diminished.

[1] See above, page 158.

Dr. Noetling.

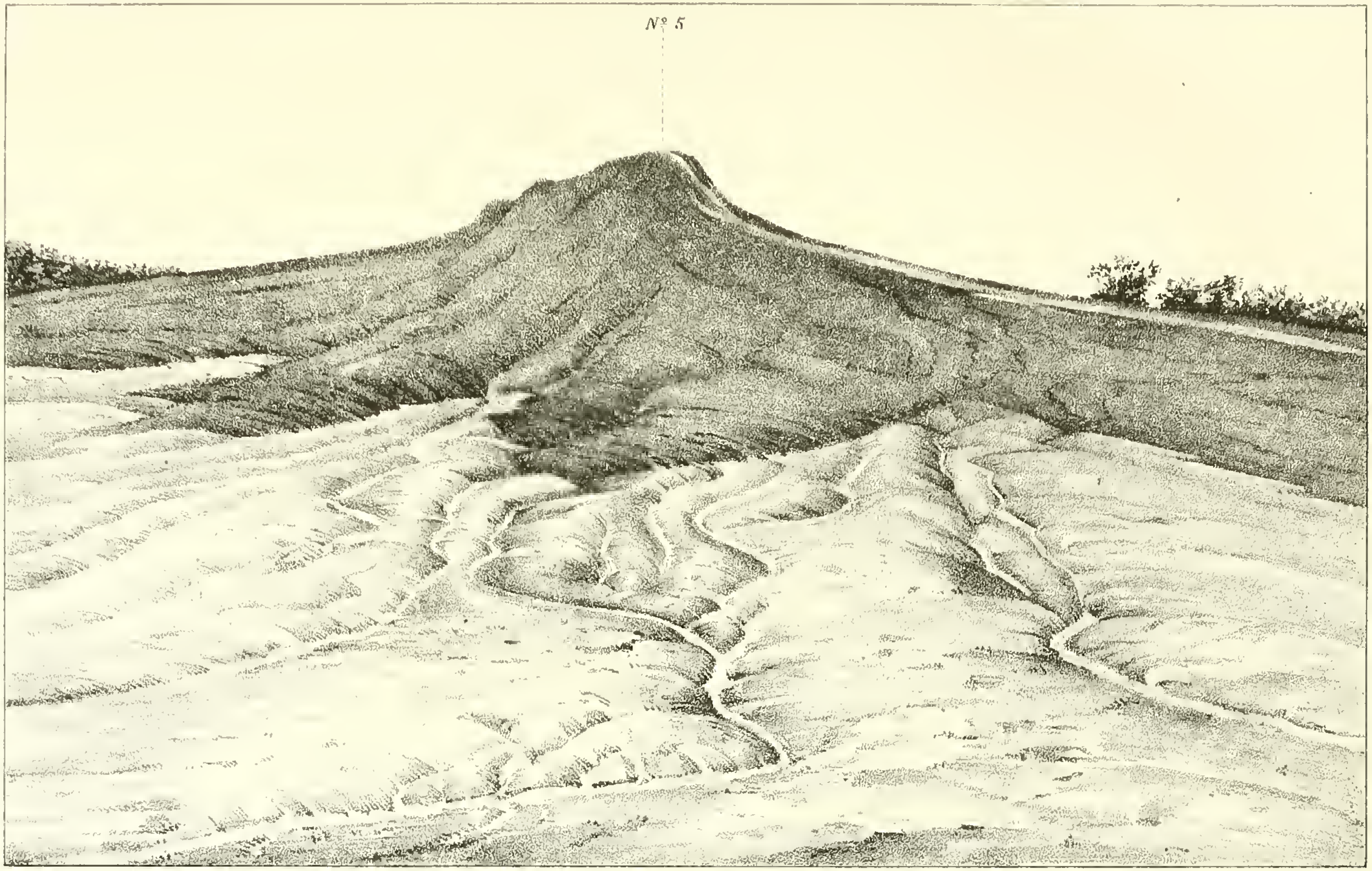
Kali Dhan Chandra Lith.

Printed at the Geol. Surv. Office.

SOUTHERN GROUP OF MUD-VOLCANOES, MINBU, IN 1889, LOOKING NORTH.

Dr. Noetling.

Memoirs, Vol: XXVII. Pt. 2. Pl. II.



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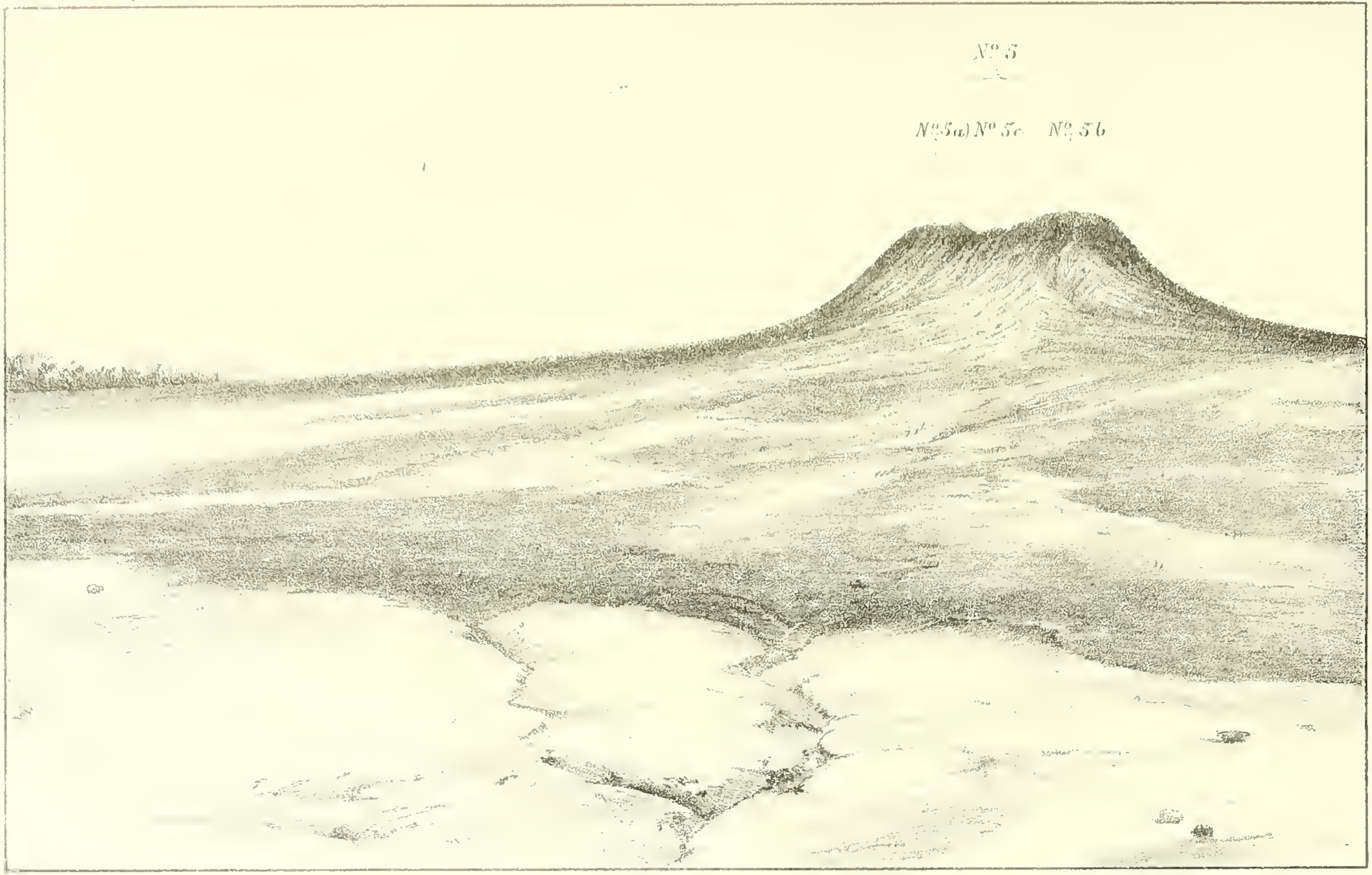
SOUTHERN GROUP OF MUD-VOLCANOES, MINBU, IN 1889, LOOKING EAST.

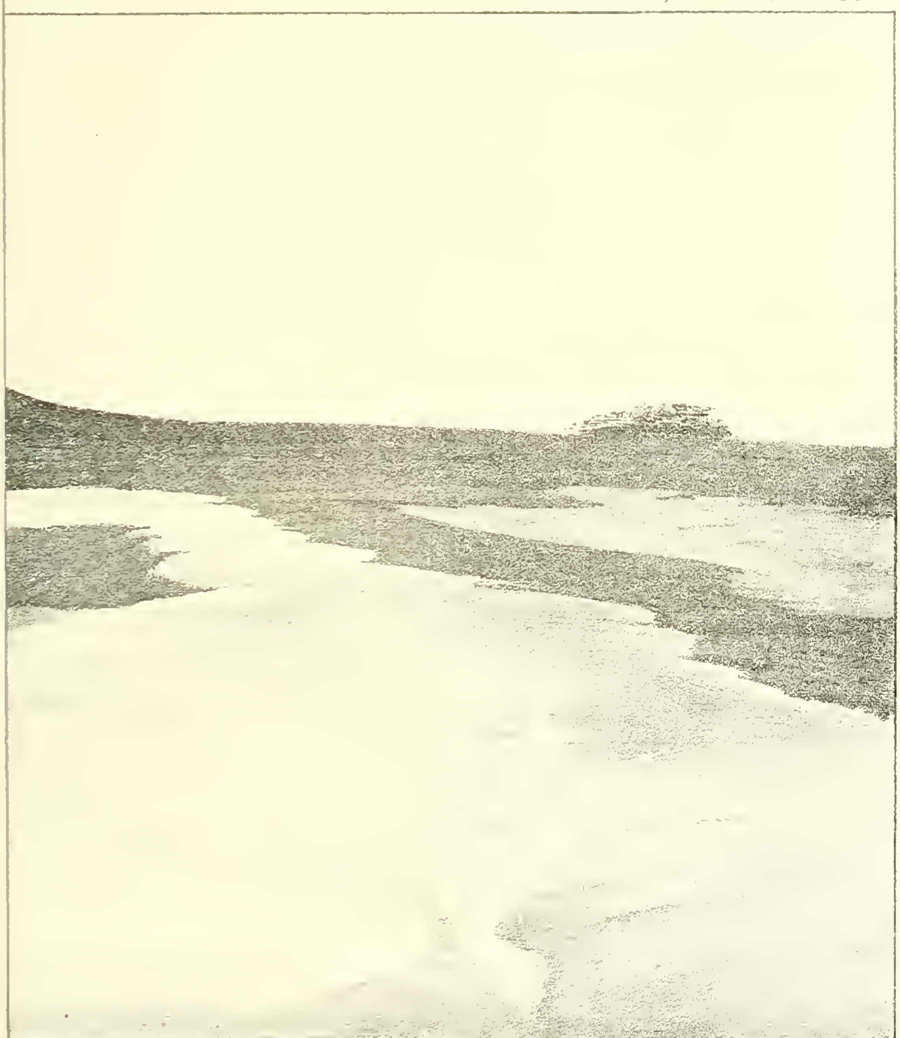
Dr. Noetling



Lal Dhar Chandra Lith.

Printed at the Geol. Surv. Office

SOUTHERN GROUP OF MUD-VOLCANOES, MINBU IN 1895, LOOKING EAST.



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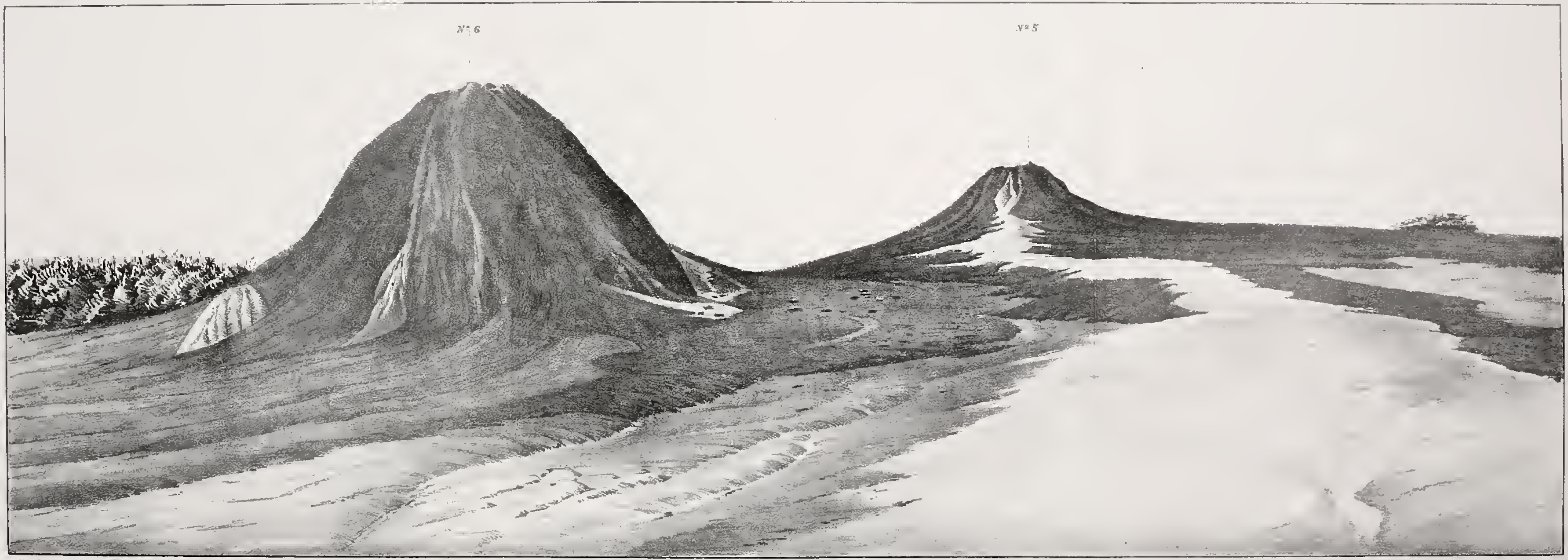
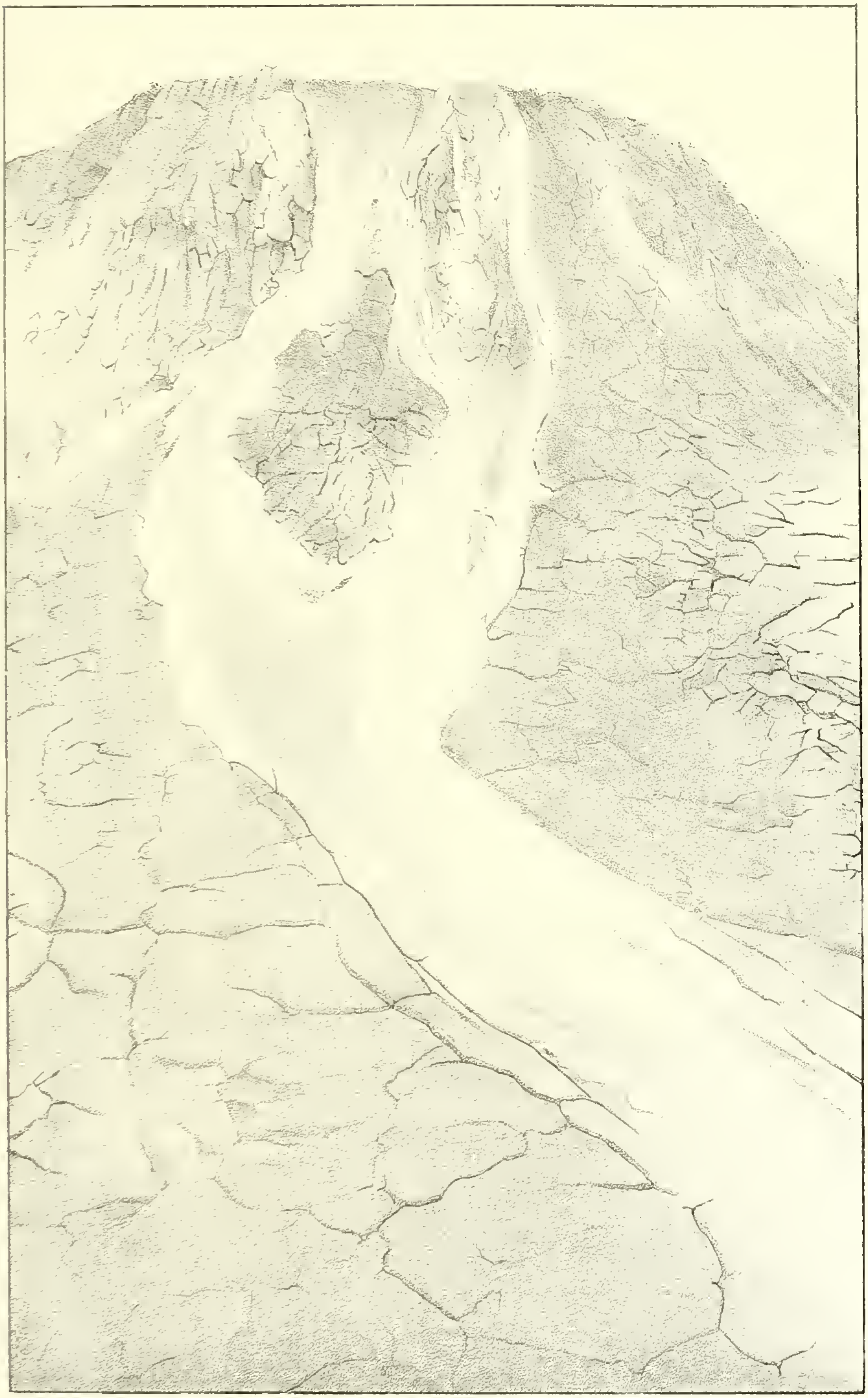


Kali Dhan Chandra Lith. Printed at the Geol. Surv. Office

SOUTHERN GROUP OF MUD-VOLCANOES, MINBU, IN 1889, LOOKING NORTH.

Dr. Noetling.



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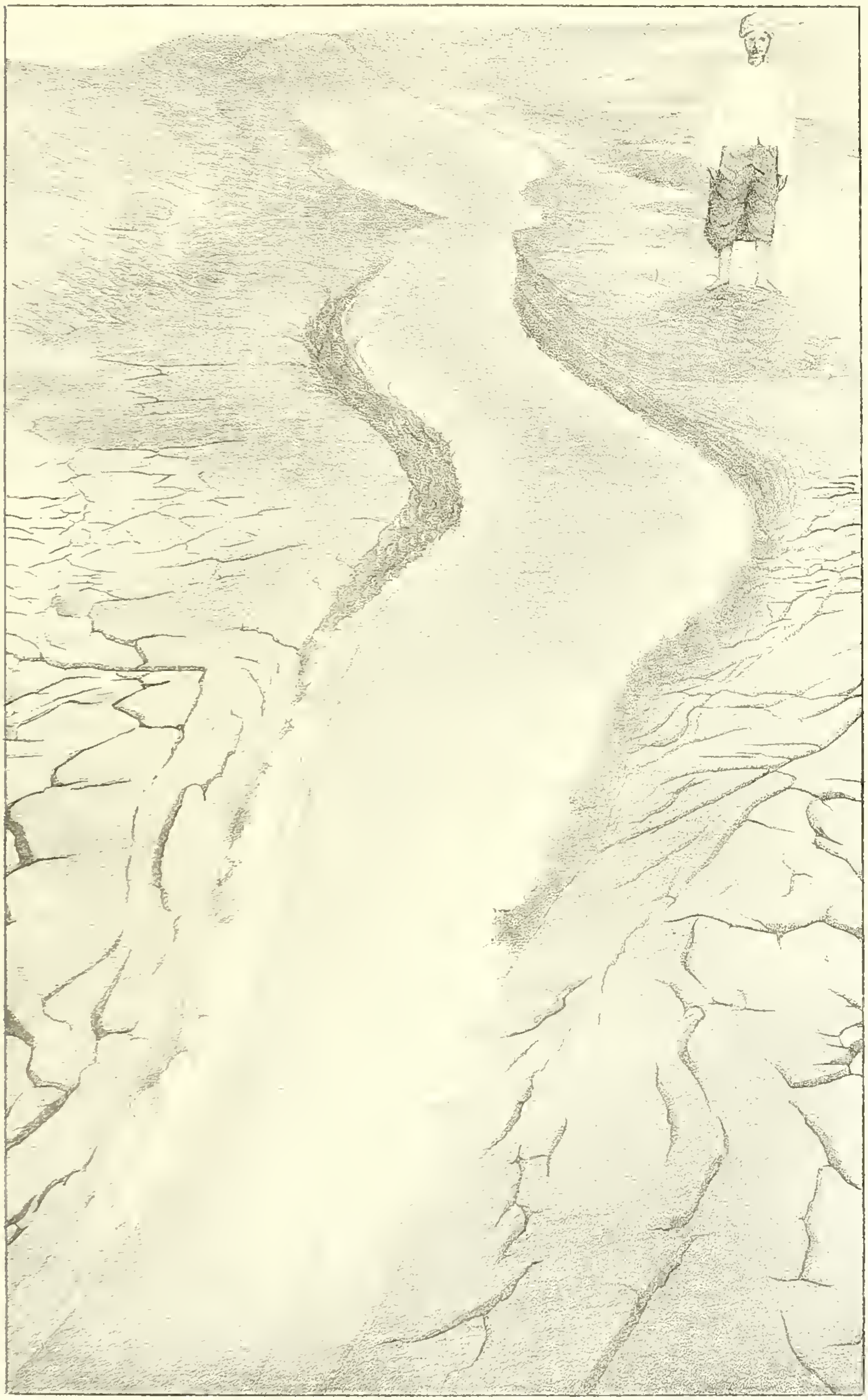
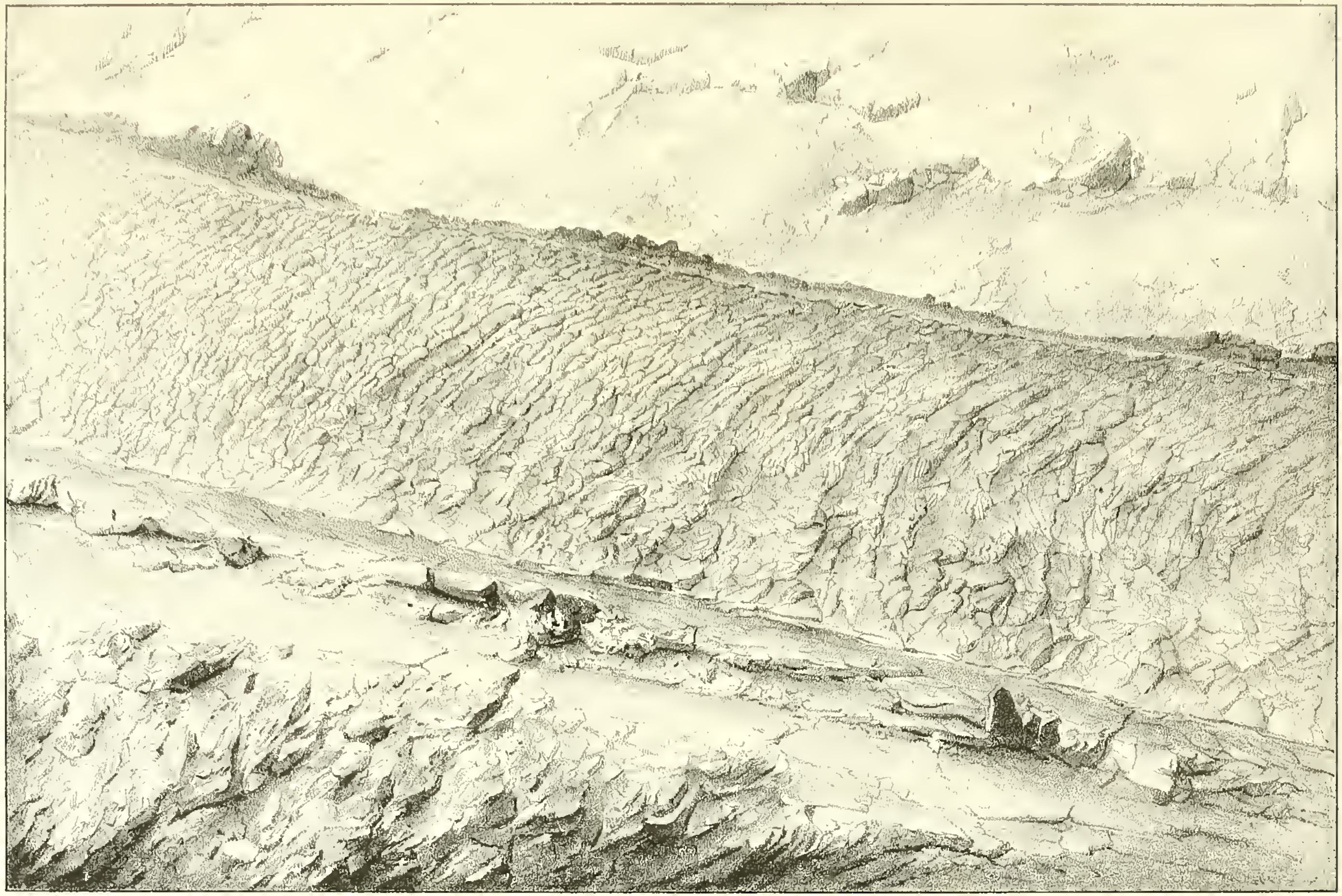
MUD-STREAM ON No. 5 MUD-VOLCANO.



Kali Dhan Chandra, Lith. Printed at the Geol. Surv. Office.

MUD-STREAM ON No. 5 MUD-VOLCANO.



Kali Dhan Chandra Lith. Printed at the Geol. Surv. Office.

MUD-STREAM ON No. 5 MUD-VOLCANO.

Dr. Noetling

Memoirs. Vol. XXVII. Pt. 2. Pl. VIII.

Kali Dhan Chandra Lith.

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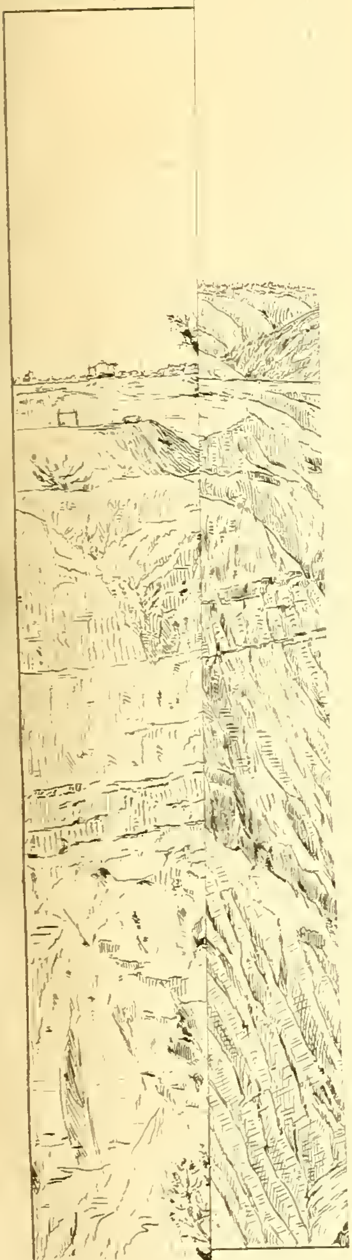
VEINS OF INTRUSIVE MUD IN THE BEMÉ RAVINE.

Dr. Noetling.



Kali Dhan Chandra

Kali Dhan Chandra Lith.

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YENANGYOUNG OIL FIELD, VIEW OF THE EASTERN SLOPE OF THE AYATPOYO.

Dr. Noetling.

Kali Dean Chanora

Printed at the Geol. Surv. Office.

Dr. Noetling.

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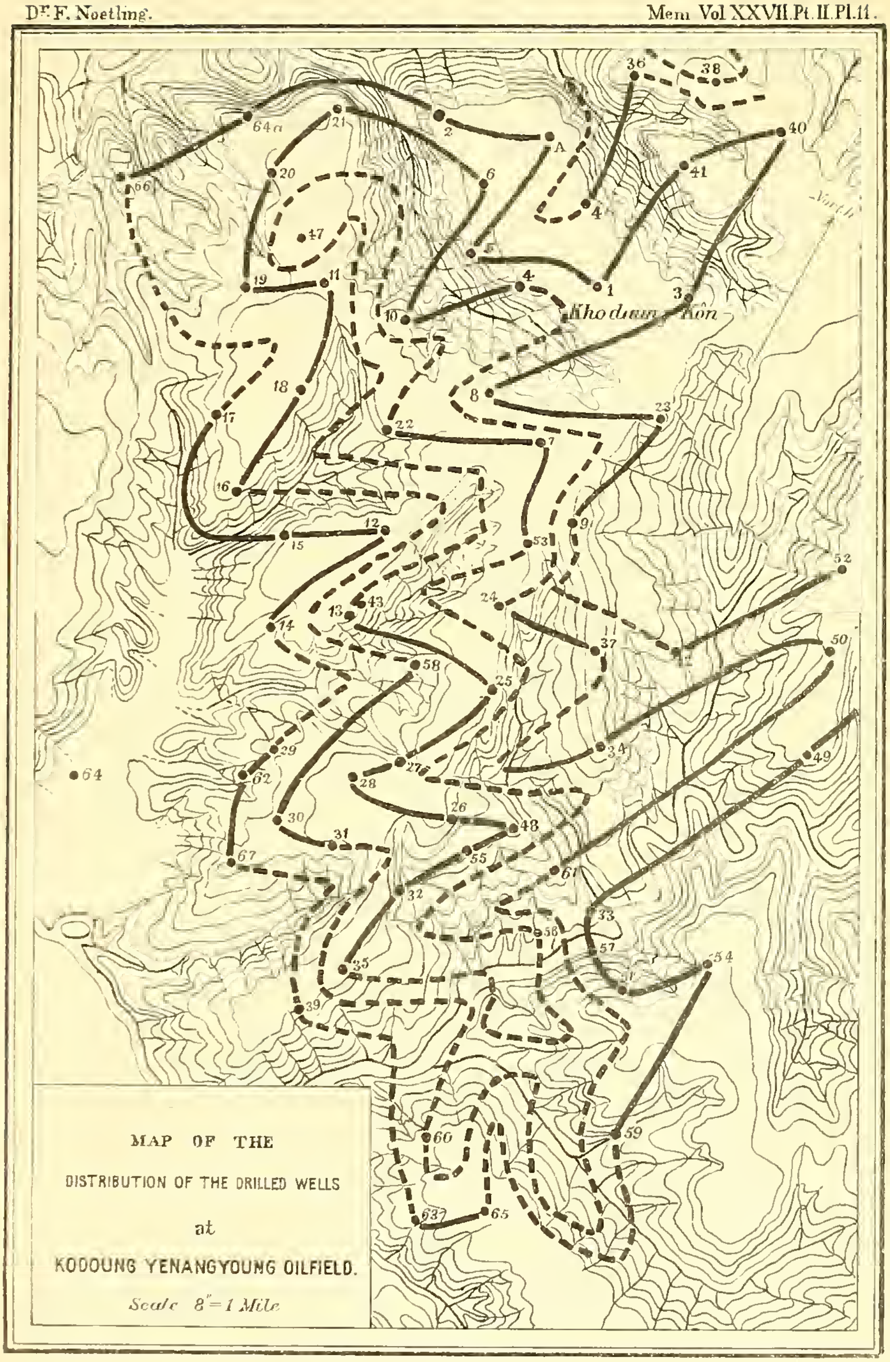
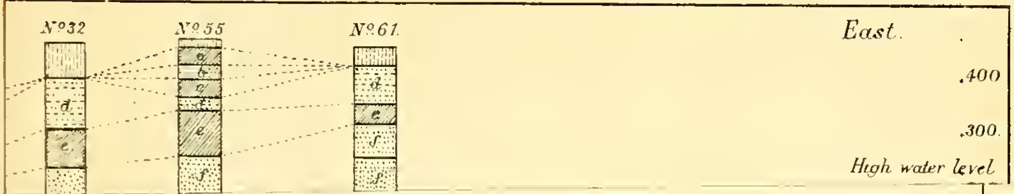
Printed at the Geol. Surv. Office.

YENANGYAT OILFIELD.

VIEW OF THE EASTERN SLOPE OF THE TAUNGSIN RANGE NEAR YENANGYAT.

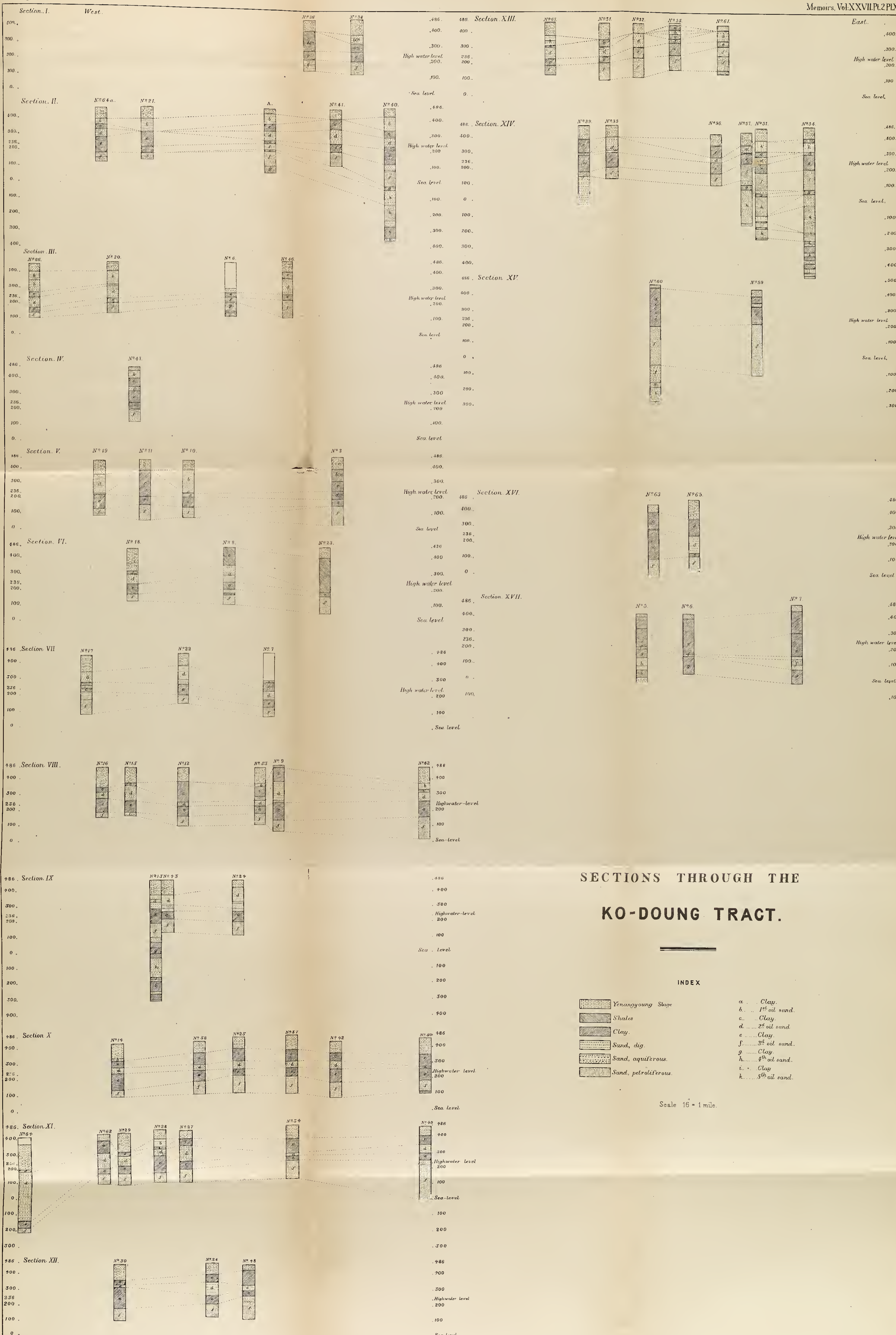
Dr. F. Noetling. Mem. Vol. XXVII. Pt. II. Pl. 11.



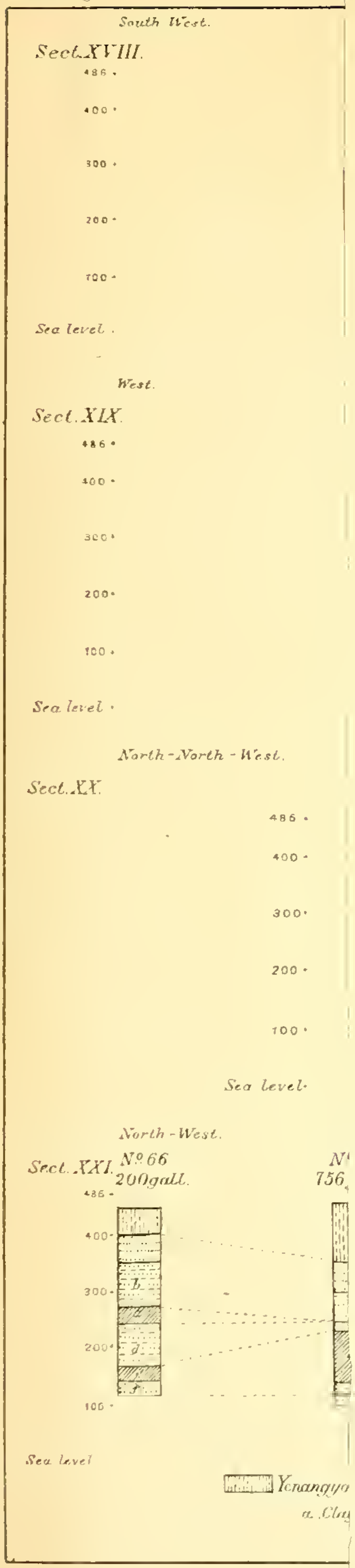


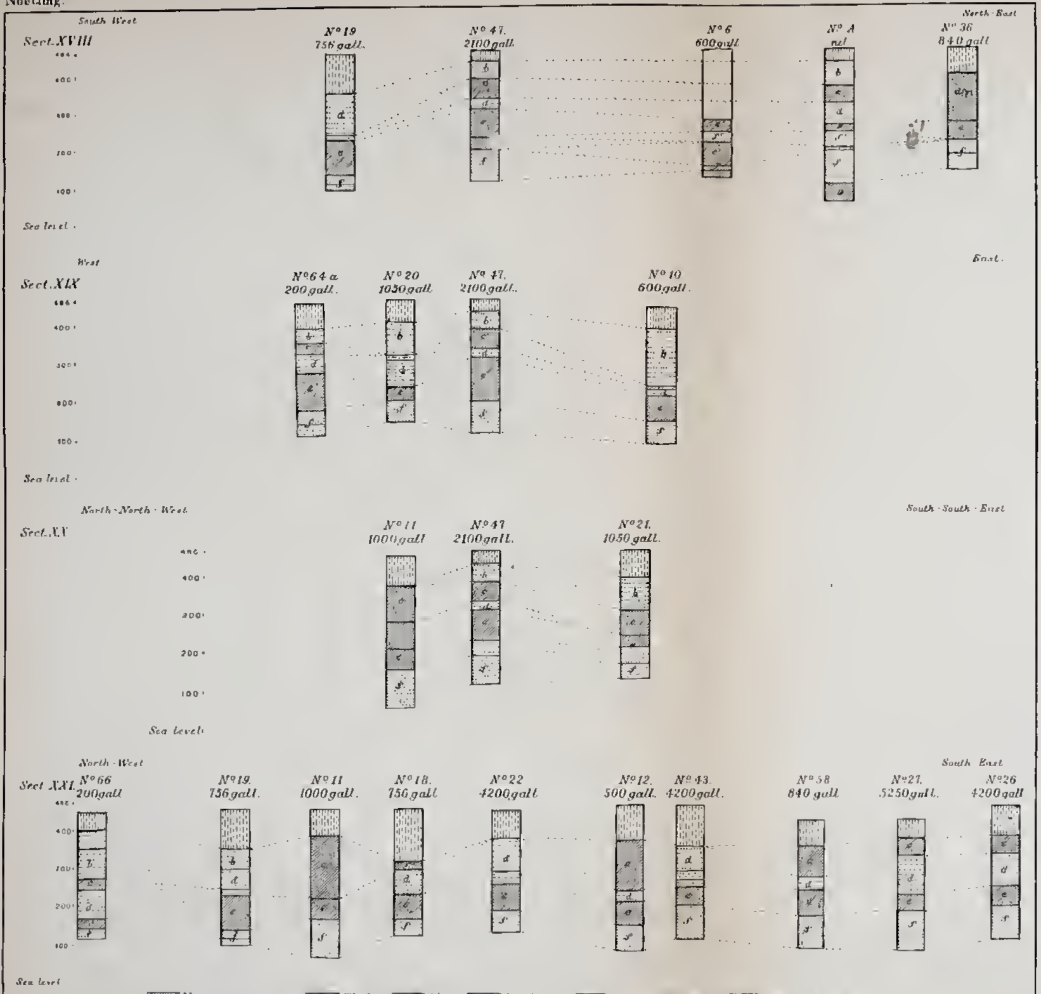
ONS THROUGH THE

-DOUNG TRACT.


West.
East.
Section. I.
Section. II.
Section. III.
Section. IV.
Section. V.
Section. VI.
Section. VII.
Section. VIII.
Section. IX.
Section. X.
Section. XI.
Section. XII.
Section. XIII.
Section. XIV.
Section. XV.
Section. XVI.
Section. XVII.
High water level
Sea level
SECTIONS THROUGH THE
KO-DOUNG TRACT.
INDEX
Yenangyoung Stage
Shales
Clay.
Sand, dry.
Sand, aquiferous.
Sand, petroliferous.
a. Clay.
b. 1st oil sand.
c. Clay.
d. 2nd oil sand.
e. Clay.
f. 3rd oil sand.
g. Clay.
h. 4th oil sand.
i. Clay
k. 5th oil sand.
Scale 16" = 1 mile.

Noetling.

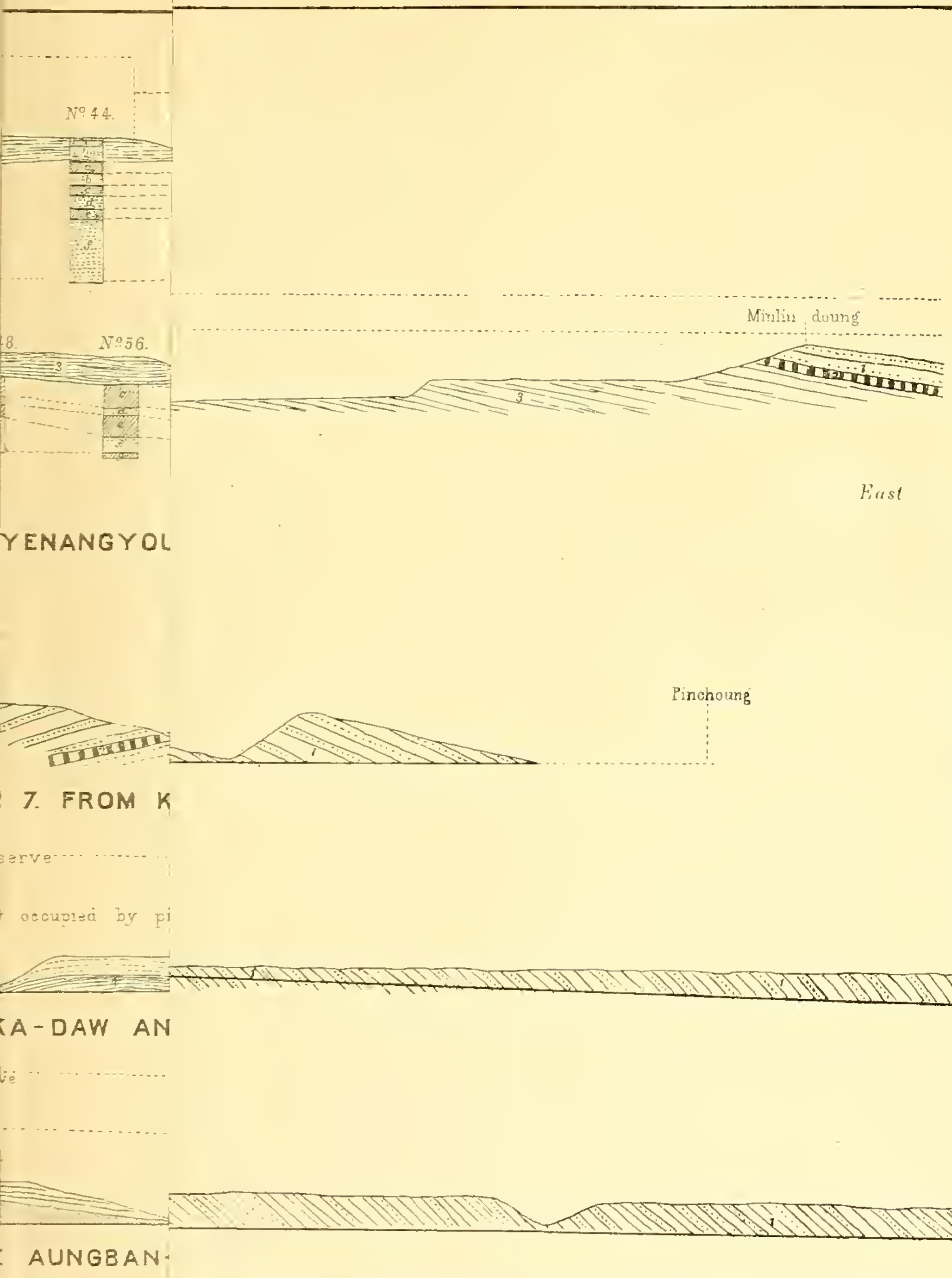

South West.
Sect. XVIII.
486
400
300
200
100
Sea level
West.
Sect. XIX.
486
400
300
200
100
Sea level
North-North-West.
Sect. XX.
486
400
300
200
100
Sea level
North-West.
Sect. XXI.
Nº 66
200 gall.
756
486
400
300
200
100
Sea level



a Clay. b 1st oil sand. c Clay. d 2nd oil sand. e Clay. f 3rd oil sand. g Clay. h 4th oil sand. i Clay. k 5th oil sand.

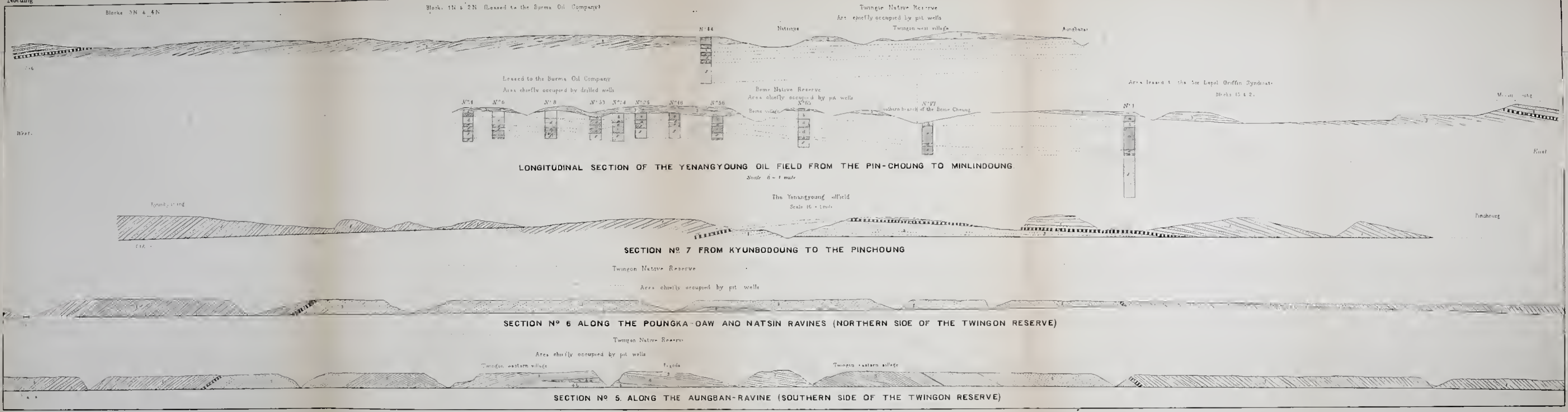
Scale 16" = 1 mile

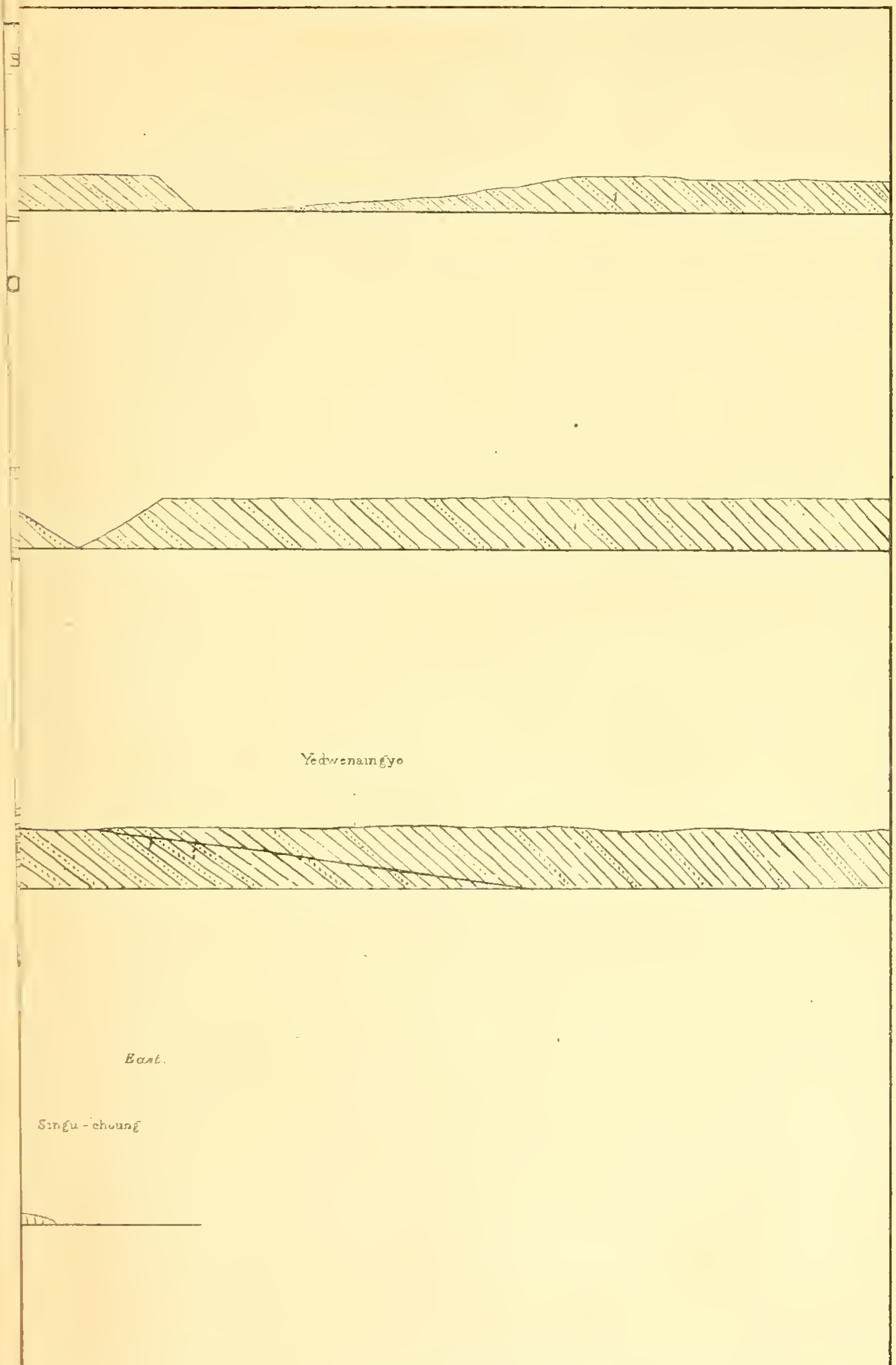
GEOLOGI

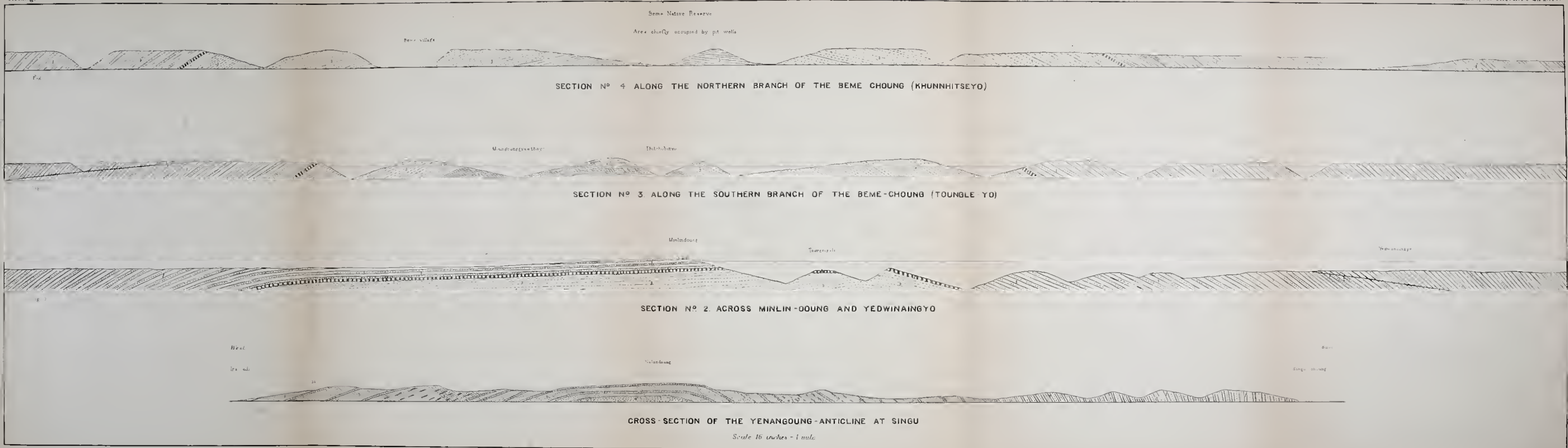

Nº 44.
Nº 56.
3
Minlin doung
3
1
East
YENANGYOU
Pinchoung
1
7. FROM K
serve
occupied by pi
1
1
KA-DAW AN
1
AUNGBAN

Noetling

Memoirs, Vol. XXVII, Pt. 2, Pl. XIV




Yedwenaingyo
East.
Singu-choung



SECTION Nº 4 ALONG THE NORTHERN BRANCH OF THE BEME CHOUNG (KHUNNHITSEYO)

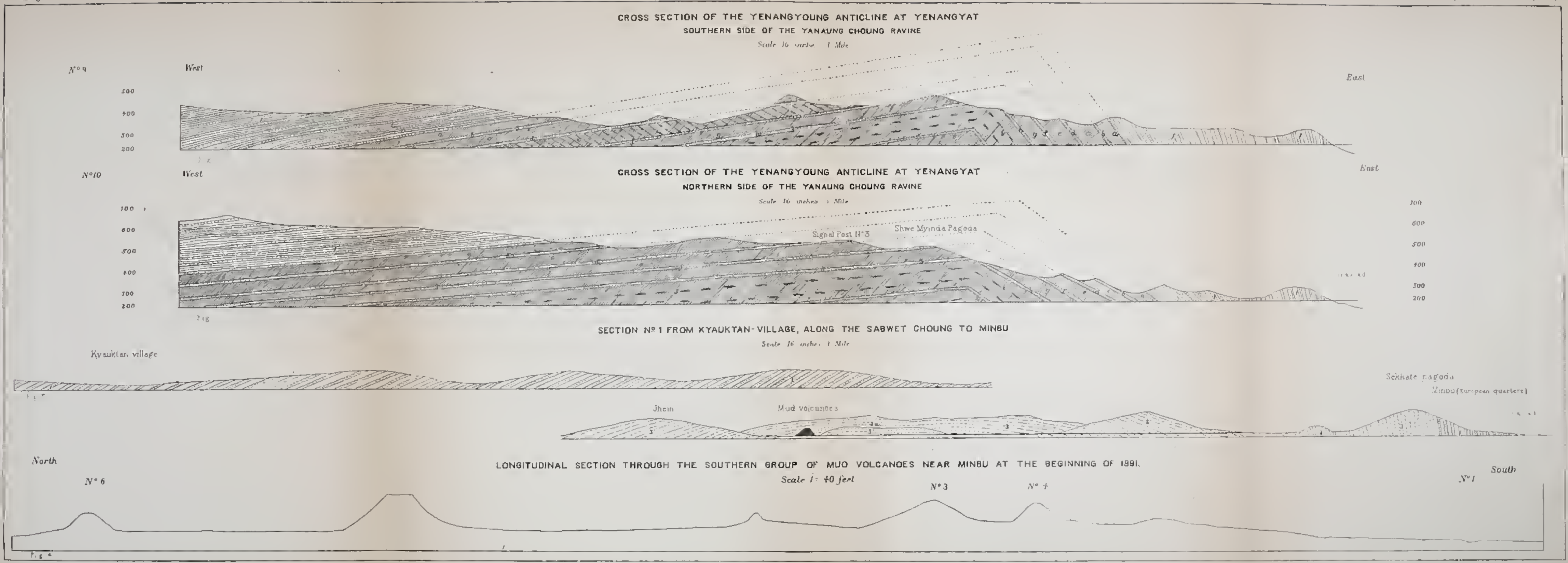
SECTION Nº 3. ALONG THE SOUTHERN BRANCH OF THE BEME-CHOUNG (TOUNGLE YO)

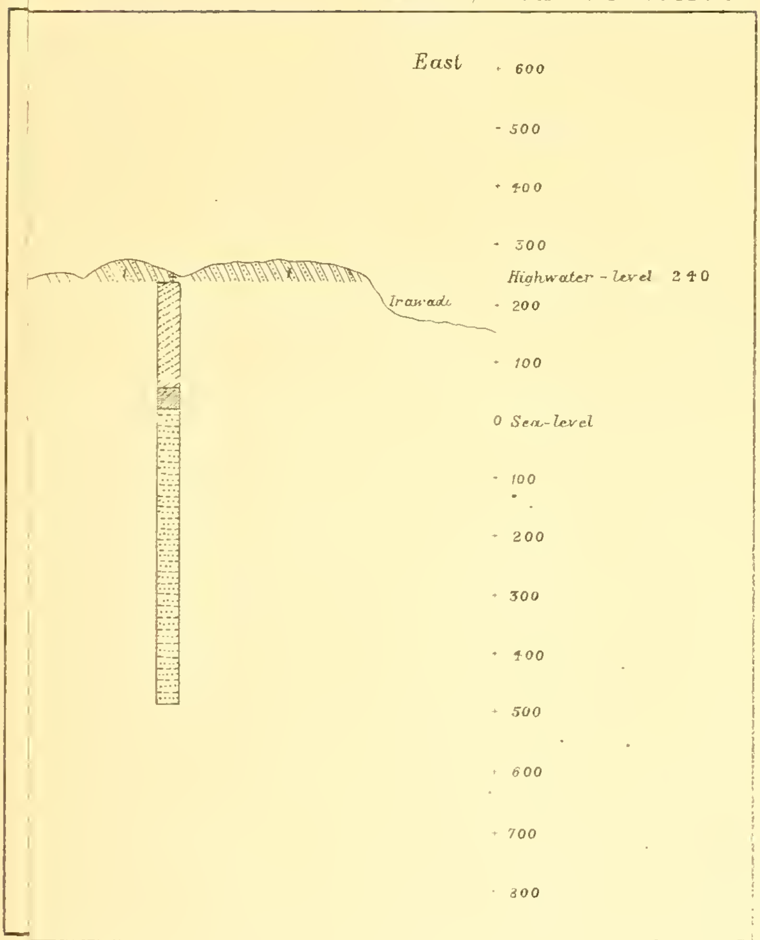
SECTION Nº 2. ACROSS MINLIN-DOUNG AND YEDWINAINGYO

CROSS-SECTION OF THE YENANGOUNG-ANTICLINE AT SINGU

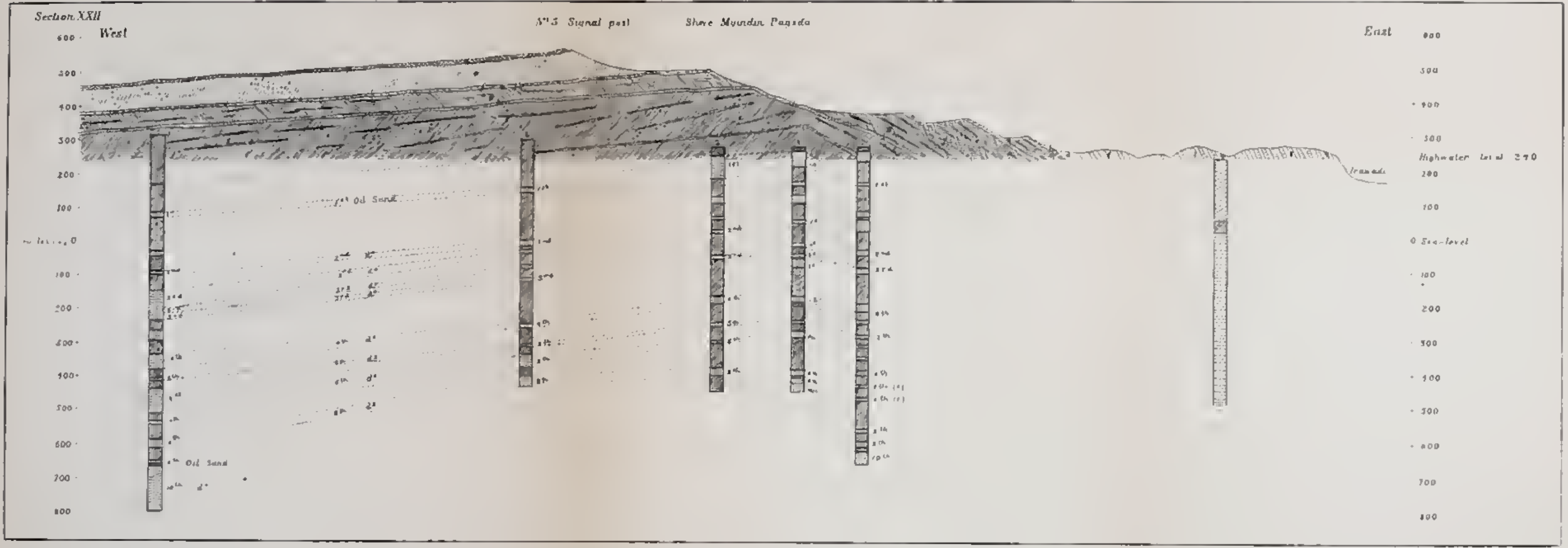
Scale 16 inches = 1 mile

OF 1
G ANTI
UNG CH
1 Mile
G ANTI
UNG CH
Mile
al Post N°
G THE
1 Mile
es
MUD VO
0 feet


CROSS SECTION OF THE YENANGYOUNG ANTICLINE AT YENANGYAT
SOUTHERN SIDE OF THE YANAUNG CHOUNG RAVINE
No 9
West
East
500
400
300
200
CROSS SECTION OF THE YENANGYOUNG ANTICLINE AT YENANGYAT
NORTHERN SIDE OF THE YANAUNG CHOUNG RAVINE
No 10
West
East
600
500
400
300
200
Signal Post No 3
Shwe Myinda Pagoda
SECTION No 1 FROM KYAUKTAN-VILLAGE, ALONG THE SABWET CHOUNG TO MINBU
Kyauktan village
Sekkate pagoda
Minbu (European quarters)
Jhein
Mud volcanoes
North
South
LONGITUDINAL SECTION THROUGH THE SOUTHERN GROUP OF MUD VOLCANOES NEAR MINBU AT THE BEGINNING OF 1891.
Scale 1: 40 feet
No 6
No 3
No 4
No 1


East
600
500
400
300
Highwater-level 240
Irawadi
200
100
0 Sea-level
100
200
300
400
500
600
700
800

ED



SECTION OF THE BORE HOLES IN THE YANAUNG CHOUNG RAVINE, YENANGYAT OILFIED

Scale 16 = 1 Mile

Memoirs. Vol. XXVII, Pt. 2.

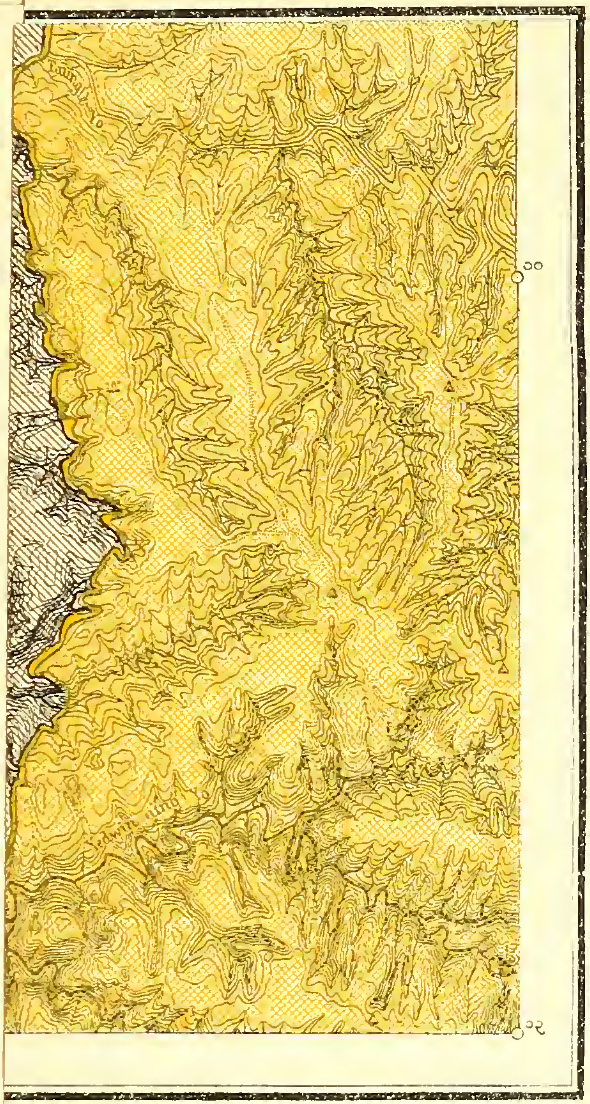


Photo-Litho., S. I. O., Calcutta


Map of the
YENANGYAUNG OIL-FIELD.
Scale 4 Inches = 1 Mile.
500 0 500 1000 1500 2000 2500 Feet
PIN CHAUNG
IRRAWADDY R.
INDEX
River-gravels ... Recent
Yellow sandstones with numerous fossil bones ... Upper
(Zone of Mastodon latidens & Hippopotamus irravadicus)
Ferruginous Conglomerate
(Zone of Hipparion antilopinum & Acerotherium perimense) Lower
Pliocene
Brown clay & Sandstone with Selenite ... Upper
Grey clay & Sandstone
- do - do - oil bearing
(Zone of Anthracotherium silistrense) ... Lower
Miocene

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within the limits of sheet 80 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenophyllum and other Equisetaceæ, with reference to the Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). On Mysorin and Atacamite from the Nellore district. On corundum from the Khasi Hills. On the Joga neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Teeth of fossil fishes from Ramri Island and the Punjab. Note on the fossil genera Nōggerathia, Stbg., Nōggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shekh Budin, and Sirgujah. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a celt of palæolithic type in the Punjab. Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwana flora with other floras. Additional note on the artesian wells at Pondicherry. Salt in Rajputana. Record of gas and mud eruptions on the Arakan coast on 12th March 1879 and in June 1843.

Part 4.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The reh soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster, in relation to Indian laterite. On some Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On some mammalian fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

Part 2.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 3.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, north-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

Part 4.—Remarks on the unification of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Turgite from the neighbourhood of Juggiapett, Kistnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi *viâ* the Sach Pass. On the South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1.—Annual report for 1881. Geology of North-west Kashmir and Khagan (being sixth notice of geology of Kashmir and neighbouring territories). On some Gondwana labyrinthodonts. On some Siwalik and Jamna mammals. The geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the (tertiary) Murree and Kasauli beds in India. On Iridosmine from the Noa-Dibing river, Upper Assam, and on platinum from Chutia Nagpur. On (1) a copper mine lately opened near Yongri hill, in the Darjiling district; (2) arsenical pyrites in the same neighbourhood; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadún Khan, Salt-range, with reference to the production of gas, made April 29th, 1881. Report on the proceedings and results of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

VOL. XVI, 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in the North-Western Provinces and Oudh.

VOL. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta parganas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On the re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

Part 3.—On the microscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Khorassan. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, South-west Khasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and Phosphatic rocks at Musuri. Work at the Billa Surgam caves.

VOL. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field-notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). On the Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud volcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and Chandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Burma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th, 1885. On the Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the petrological character of the Amphibolites and Quartz-Diorites of the Sutlej valley.

Part 2.—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive Group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

Part 3.—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

Part 4.—On the occurrence of petroleum in India. On the petroleum exploration at Khátan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1.—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-Garhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

Part 2.—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

Part 3.—The retirement of Mr. Medlicott. Notice of J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

Part 4.—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section II. The iron industry of the western portion of the district of Raipur. Notes on Upper Burma. Boring exploration in the Chhattisgarh coal-fields. (Second notice.) Some remarks on Pressure Metamorphism, with reference to the foliation of the Himalayan Gneissose-Granite. A list and index of papers on Himalayan Geology and Microscopic Petrology, published in the preceding volumes of the Records of the Geological Survey of India.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of nodular stones obtained by trawling off Colombo.

Part 2.—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sangar Marg and Mehowgale coal-fields, Kashmir.

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