The Diamond Mines

OF

Panna State in Central India

By

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PREFACE

MANY writers and geologists have visited the Panna diamond mines since 1820; there is therefore a fair amount of literature on the subject. This brochure is an attempt to put before the general public all the facts worth knowing in connection with the Panna diamond mines. The writer has had exceptional opportunities of studying the diamondiferous formations in different parts of the State during his stay of 2 years and 3 months in Panna. Under his supervision a series of boreholes aggregating to a total depth of more than 2,000 feet were put down in different parts of the Panna State. This is the first time that borings were put down in Panna territory. One of the borings—that at Majgawan has revealed the fact that the formations occurring there consist of an agglomeratic tuff resembling, to a certain extent, the "blue-ground" of Kimberley.

Though nature has bestowed on Panna State the gift of the most precious of gemstones, it has been made with rather a niggardly hand in comparison with the enormous store of diamonds occurring in South Africa where millions of carats have already been mined and millions and millions lie in reserve. There is no reason, however, why the store of diamonds occurring in Panna State should not be systematically won as labour is cheap and the workable diamondiferous ore occurs from within a few feet to about 70 feet from the surface in the different fields which are being worked at present. Besides, the agglomeratic tuff which occurs at Majgawan in the shape of a pipe may hold a very rich store of diamonds at present undreamt of.

The writer wishes to express his very sincere thanks to H. H. The Maharaja Saheb of Panna for the keen

interest which he evinced in the writer's work and for his appreciation of it ; also for giving the writer all the necessary facilities for carrying out such work. To Mr. M. A. Tana, the then Dewan, his best thanks are due for the promptness with which he disposed of all questions relating to his work, for his unfailing courtesy, and for his co-operation without which the work entrusted to the writer could not have been finished during the period at his disposal.

BOMBAY, 15*th May*, 1930 K. P. SINOR.

THE DIAMOND MINES OF PANNA STATE IN CENTRAL INDIA.

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CHAPTER I.

GENERAL DESCRIPTION.

PANNA STATE was the centre of active diamond mining in the past as is evidenced by innumerable old workings which extend from Majgawan Lat. 24°-38′: Long. 80° -4′ through Barour, Manour, old Panna and Kalianpur to Itwa, Bargari, Birjpur and Gehra lat. 24°-49′: long. 80° -30′, a distance of nearly 30 miles in a south-west to north-east direction. It is in this belt that the most productive diamond mines of Panna are situated. Another diamondiferous zone which is situated about 20 miles to the east of Panna was also worked in olden times, particularly near Durgapur, Singpur, Tindini and Mohra, the most famous mines in this zone being the Udesna mines close to Sakaria which is situated 8 miles to the south-east of Panna. Many of the famous old diamond mines in Panna State, *viz.*, those of Shahidan, Majgawan, Itwa and Udesna had been visited and described by Capt. Franklin, Jaquemont, Rousselet, Medlicott and Capt. Pogson many years ago. About 25 years ago the mines were visited by E. Vredenburg of the Geological Survey of India who summed up his observations regarding the Panna diamond fields in the Records of the Geological Survey of India, Vol. XXXIII.

One thing which stands out pre-eminently above all others from the records and observations of the previous visitors to the Panna diamond mines is that the diamond mining industry must have been very profitable in olden times and that mining was conducted on an extensive scale. The only places which have been worked during the last 10 or 12 years are those of Shahidan and Itwa. In fact most of the diamond mines had been closed down during the minority of the present ruler of the Panna State. It is only recently that efforts are being made to revive and rejuvenate the diamond mining industry which must have been one of its greatest assets in the past. The Majgawan mines and the Udesna* (Maharajpur) mines, two very famous old mines, are even at present unworked.

Although the Panna diamond mines were worked in King Akbar's time, *i.e.*, in the latter part of the 16th century, tradition has it that most of the mines were in disuse and their sites completely forgotten at the time when Raja Sabha Singh was the ruler of Bundelkhund. The reopening of the mines is attributed to the efforts of one Pran Nath, a preacher and spiritual leader who came to Panna in 1742. He is said to have advised Raja Sabha Singh to open out the mines after he had discovered the old sites. Because of this, he rose to high favour. There is in Panna a temple dedicated to him.

Former Revenue from Diamond Mines.

From the estimates given by different writers regarding the revenue derived from the diamond mines in former times it is quite clear that the State obtained a handsome income from the diamond mining industry. Thus by one writer it has been stated that diamonds worth about 8 Lakhs of rupees were annually produced in Panna State in the

* I am informed that the Udesna mines have been opened to the public since July 1929.

time of the Moghul Emperor Akbar and that even in Ali Bahadur's time the revenue to the State from that source was considerable. In the year 1750, *i.e.*, in Raja Chhatrasal's time the duties and profits from the diamond mines amounted to £40,000 per annum. According to Franklin the total yield from the sale of diamonds amounted to £120,000 per annum of which the Panna State received one quarter, *i.e.*, about £30,000. Rousellet estimated the income from the diamond mines in 1807 at from 1,500,000 to 2,000,000 franks, *i.e.*, from £60,000 to £80,000. The present revenue to the State from the sale of the diamonds is only a small fraction of what the State used to get according to Rousellet and Franklin. There were a number of diamond cutters in the past in Panna proper and they used to do brisk business. Many of them left Panna after the mines had been practically closed. At present there are only a few craftsmen in Panna who do the work of cutting and polishing the gems. The Panna diamond mines received a considerable setback after the discovery of the very rich diamond fields of South Africa in 1870. Almost a death-blow was delivered to the Panna diamond industry due to their discovery from which it has never sufficiently recovered.

Geological formations occurring in Panna Territory.

The following formations occur in Panna territory in order of age, the lowest being the oldest and the highest the most recent :—

Recent and sub-recent alluvium.

Basic volcanic formations of the upper Cretaceous period commonly known as the Deccan Trap.

Lameta beds.

Vindhyan beds.

Bijawar rocks.

Granites and gneisses of the Archæan period.

I will describe these formations here very briefly as the geology of the various beds has been fully described in many of the publications of the Geological Survey of India. In order to give an idea of the actual horizon at which the diamond bearing conglomerate occurs and also to give an idea of the age of the various pebbles found in the conglomerate, only a cursory description is given below.

Granites.—The granites largely occupy the northern part of Bundelkhand which is a comparatively low-lying plain as compared with the southern part of Bundelkhand which is mostly covered by the hard and weather resisting formations of the Vindhyan system. I have examined the granites occurring in the Ken river from near Baharganj and Marla up to Chattarpur, in the vicinity of the Panna-Nowgong-road; also the granites occurring at the base of the Bisramganj Ghat up to Ajaigarh, and the associated quartz reefs and the dark coloured basic dykes occurring in the granites. The mineral composition of the granites and the basic volcanic rock intruded in them will be given in the petrographic notes in another part of this report.

Bijawar Rocks.—The Bijawar beds are exposed in Panna territory in a thin strip between the granite formations and the Semri sandstone near Pathar Chauki. There is another small exposure of this rock to the south-east of Baharganj. Here I observed the characteristic Bijawar conglomerate consisting of bright red Jasper, dark-red hæmatitic Jasper, black quartzite, yellow siliceous pebbles, hornstones and vein-quartz in a coarse-grained siliceous matrix.

PLATE I.

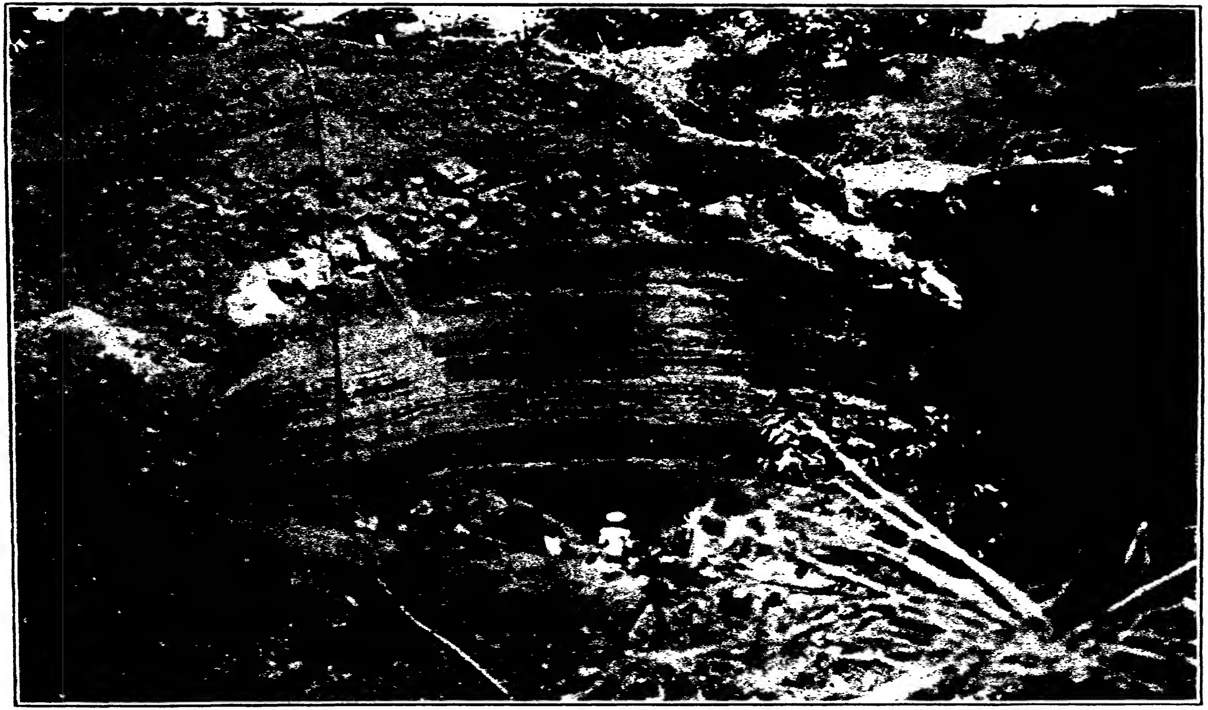

Photo by K. P. Sinor.

FIG. 1.

Section of a pit in Shahidan showing clearly the different strata consisting of made-ground, boulder-bed, and green and chocolate-coloured shales.

The Vindhyan formations.

The Vindhyan formations are economically the most important in Panna State as it is in these beds that the diamond bearing conglomerates of Panna occur. The Vindhyans are divided into two systems, the Upper and the Lower Vindhyan systems.

Lower Vindhyans.—The Lower Vindhyans are characterized by two main divisions, the Palkua and the Semri, the different beds composing the same being as follows:

Palkua Division ..	Tirhowan limestone. Palkua shales. Dalchipur sandstones. Dalchipur conglomerate.
Semri Division ..	Semri shales. Semri Limestone. Semri sandstone.

Details regarding these formations will be found in the memoirs of the Geological Survey of India, Vol. II, by H. B. Medlicott.

Upper Vindhyans.—The Upper Vindhyan system was very carefully studied by F. R. Mallet of the Geological Survey of India. Detailed descriptions of the beds occurring in this system will be found in the Memoirs of the Geological Survey of India, Vol. VII, Part I. The Upper Vindyan is sub-divided into two stages, the Ken and the Bhander. The Ken stage is divided into the Son series and the Tons series while the Bhander is divided into the Haveli and the Betwa series. The following table gives the sub-divisions of the different stages and series:—

Bhander.	Betwa Series .	Upper Bhander sandstone.
	Haveli series ..	Sirbu shales. Lower Bhander sandstone. Nagode limestone. Ganugarh shales.

Ken.	Tons series	Rewa division	Upper Rewa sandstone with diamond bearing conglomerate in uppermost bed.
			Jhiri shales with diamondiferous conglomerate at base.
Ken.	Son series (Lower Vindhyans)	Kaimur division	Kaimur sandstone. Upper, thinner.
			Kaimur sandstone. Lower, thicker.
			Kaimur conglomerate
			Kaimur shales.
		Palkua division	Tirhowan limestone.
			Palkua shales.
			Dalchipur sandstone with conglomerate at base.
		Semri division	Semri shales.
			Semri limestone.
			Semri sandstone.

Sandstones, shales and limestones form the three principal rocks of this system, which extend for hundreds of miles. The three principal sandstone formations are the Kaimur, the Rewa and the Bhander. The Kaimur sandstones are geologically the oldest of the three and topographically also they occupy the lower levels. The Rewa sandstone is situated above the Kaimur and below the Bhander sandstone. The escarpments formed by these three sandstone masses are very characteristic and conspicuous. One can see them extending for miles. The shaly formations being soft, and therefore considerably prone to weathering, have given rise to broad fertile plains and valleys. In Panna territory, the Kaimur escarpment runs in a line to the north of Majgawan, Panna and Itwa. The Upper Rewa sandstone escarpment stretches for miles to the south of these places while the Bhander escarpments can best be seen from the low-lying plain near Maihar and Amdara railway stations. The limestones are more developed in the Haveli series than in any other formation and form an important economic product in those parts where they are largely exposed as at Satna, Sohawal, Nagode and Maihar.

Lameta Beds.—The Lameta beds have a very restricted occurrence. They are only exposed in a few places to the South West of Panna near Sukuha, Manki and Kherband. This formation which originally had a wide distribution has been denuded away.

Deccan Trap.—Basic volcanic rocks of Upper Cretaceous age occur in a few places to the South West of Panna on the top of the Lameta beds mentioned above. They occur in the form of outliers. They are the remnants of the basic volcanic beds which at one time must have stretched right up to Baghelkhand. The largest exposure of Deccan Trap in Panna territory is near Buxwaho close to Saugor and Damoh districts, in the westernmost part of the State.

Recent and sub-recent formations.

True alluvium occurs in Panna territory only in the proximity of river beds. In the northern part of Bundelkhand which is outside the limits of Panna territory true gangetic alluvium occurs. Calcareous tufa is a sub-recent formation formed by water highly charged with calcium carbonate from which part of the salt is deposited on evaporation. A typical example of such tufa is in the gorge of the Kaimasan river near Barour where the river plunges headlong from a height of nearly 200 feet. It is not a very extensive deposit but the lime yielded on burning the tufa is very good. Another such deposit is near Kachha, not far from Barour. At the waterfall near Pather Chauki there is another deposit of calcareous tufa, the rock in this case being crystalline. For use in Panna, the tufa from the bed of the Kaimasan river as also that near Kachha are both quarried and burnt at Barour for making lime.

Geological Horizon of the Panna diamondiferous conglomerates.

The diamond fields of Panna State are situated in two distinct geological horizons, one known as the Upper Rewa sandstone of the Rewa division of the Vindhyan series and the other known as the Panna shales lying below the Rewa sandstone. Very good exposures of the Upper Rewa sandstone and the underlying chocolate-coloured and olive-green shales may be seen in many places near Panna, the sandstones forming conspicuous escarpments. We shall first deal with the lower formation, namely, the Panna shales, in which diamond mining is at present carried on. The diamond is found in this horizon in a conglomerate which occupies a position at the base of the Panna shales and on the top of the Upper Kaimur sandstone. This conglomerate is very hard and very tough. It consists essentially of pebbles of quartzite, jasper, vein-quartz, hæmatite and limonite cemented together by a quartzose matrix. A characteristic feature of this conglomerate is the presence of a number of clay pellets some of them greenish, some yellowish and some white, which probably represent the decomposed fragments of the Palkua and Semri divisions of the Lower Vindhyans. The quartz pebbles have almost certainly been derived from the quartz reefs which occur very largely in the Bundelkhand granite. The quartzite pebbles probably belong to some of the Lower Vindhyan beds. The presence of a hard indurated greenish quartzite used to be looked upon by old miners as a favourable indication of the presence of diamonds and even at the present day this belief is current among the workers, though as a matter of fact this green indurated quartzite locally called "Kansya" is never crushed and treated for diamonds. The jasper pebbles occurring in the conglomerate must have been derived from the Bijawar conglomerate.

The size of the individual pebbles varies within wide limits. At times the conglomerate is very coarse. I have seen pebbles from three to five inches in diameter in some of the beds. The yield of diamonds is usually large from the coarse variety of the conglomerate and as a rule bigger diamonds are obtained from a coarser conglomerate than from a fine-grained one. The character of the conglomerate is not very constant over large areas. In fact, in one and the same field I have noticed certain variations in the composition and size of the pebbles forming the conglomerate. As a rule, however, the deep workings of the Shahidan mines to which reference will be made later, yield a coarse conglomerate. The conglomerate obtained from other workings as for instance at Barghari, Bijepur, &c., is not so coarse. The clay pellets in the Shahidan conglomerate are often above two inches long. It appears that this conglomerate was deposited on an uneven floor of the Upper Kaimur sandstone and the thickness of the conglomerate is therefore not constant. From some workings, a conglomerate only a few inches thick is obtained whereas in others, as for instance at Barghari, the thickness of the conglomerate is full 5 feet. In some cases there is a gradual transition from the sandstone on which it rests to the conglomerate bed proper. There is not as a rule any division or parting separating the conglomerate from the sandstone. At Kalianpur, Laxmipore and other places the conglomerate has been found to occur not in between the Kaimur sandstone and the Jhiri shales but at a higher level.

Minor variations regarding the stratigraphical position of the conglomerate have been observed even in one and the same field, as at Shahidan. In the eastern part of Panna territory, as at Bijepur, Itwa, and Barghari the variation is more pronounced in as much as the diamondiferous conglomerate is separated from the Kaimur sandstone by a variable thickness of another group of shales known as the Itwa shales in which a sandstone band is also intercalated. These variations will be fully dealt with when describing the different mines.

Upper conglomerate occurring in the Upper Rewa sandstone.

The newer conglomerate has not been seen anywhere 'in situ' up till now. The gravels derived from this conglomerate are however characterized by quite a large proportion of vein-quartz pebbles and boulders as could be seen even at the present day in the old dumps lying in the Udesna gorge where mining was active once upon a time. The workings connected with the newer conglomerate, most of which are situated on the Upper Rewa sandstone plateau are shallow or "Chhila" workings with the exception of a few workings in the gorge of rivers which cut the sandstone scarp as the old Udesna mines, where the mining was mostly alluvial.

Classification of workings.

In the lower conglomerate which occurs between the Panna shales and the Upper Kaimur sandstone three kinds of workings are met with. These may be called "deep workings, shallow workings and alluvial workings."

Deep workings are those in which the diamondiferous conglomerate proper is worked out from underneath the shale beds overlying it. The Shahidan mines are a typical example of 'deep' workings. The depth of the pits may

PLATE II.

Photo by K. P. Sinor.

FIG. 2.

A corner of a pit sunk by the Rajputana Minerals Syndicate at Shahidan in 1927 showing the boulder-bed resting on the green and chocolate-coloured Jhiri shales in which a fold can be seen. In the bed overlying the Jhiri shales two very large blocks of sandstone are seen.

be 25 feet and upwards, the maximum depth reached being 70 feet in the Shahidan field.

Shallow workings known locally as " Chhila " workings are those in which the diamond bearing rock is a friable conglomerate occurring at a depth of 5 to 12 feet below the surface. Above the friable conglomerate a layer of gravel usually occurs which is also diamondiferous. This layer of gravel or 'kakru' as it is locally called, consists of pebbles of quartzite, jasper, sandstone, and veinquartz, derived from the original conglomerate, mixed with laterite pebbles occurring in the soil.

True alluvial workings.

In alluvial workings proper there is no trace of the original conglomerate. The diamond-bearing bed consists of the products of weathering of the original conglomerate which have been redistributed and which form a definite layer at varying depths from the surface. In some places as at Itwa and Maharajpur, pits from 25 feet to 40 feet deep are usually sunk to extract the diamondiferous gravel. In other places such as at Kalianpur and Ganeshpur the diamond bed occurs at a depth of from 10 to 20 feet.

The chief difference between workings of the second class, *viz.*, shallow workings and alluvial workings proper is that in the former it is usual to find the original conglomerate also in a weathered condition and shaly layers are also met with, whereas in the latter there are no shales nor any decomposed conglomerate associated with the gravel.

Mining methods.

It has been recorded by previous visitors like Franklin (1833) and Jaquemont (1841) to the Panna diamond mines that the mining methods then adopted, *i.e.*, in 1833 and 1841 were very primitive. The same primitive methods were in vogue in 1904-05 when Vredenburg visited the Panna mines on behalf of the Geological Survey of India with a view to gather as much information as possible about the different diamond workings which was published in 1906 in Vol. XXXIII, Part 4 of the Records of the Geological Survey of India. The methods of mining and concentrating as witnessed by him were exactly the same as those seen and recorded by Franklin and Jaquemont and although 25 years have elapsed since Vredenburg's visit it must be confessed that the methods of mining the diamondiferous ore are just as primitive as those described by the early observers.

Every year, the miners sink a few pits in any part where they like. There are no restrictions as to the site of the mine or the size of the pits sunk. When the necessary site has been selected by a miner with a view to suit his own purse and requirements, irrespective of any other consideration, he sinks a pit the size of which depends on the amount which he is prepared to spend. The size of the pits varies from 15 feet to 40 feet in diameter. The chief aim of the miner is to get out as much of the diamondiferous conglomerate as possible with the lowest possible outlay. The depth at which the diamondiferous conglomerate occurs, varies in different parts of the diamond fields as the strata dip a little to the south. The miner usually starts work at a time so calculated that the diamondiferous layer is exposed some time in the latter part of April or in May when the water level goes down considerably. As the conglomerate is very hard and tough the miners usually cover its surface with big logs of wood and light a fire. Due to the sudden expansion, fissures are produced in the conglomerate bed which is then opened out by wedges.

In wet mines some arrangement for keeping them dry has to be used. Various primitive devices are used for emptying out the water. Miners with a small capital usually employ a number of women who carry the water from the pit bottom to the surface in earthenware vessels. In very wet mines a familiar primitive device known as a "Persian Wheel" is used to dewater the mine. It consists of a wheel on which vessels are attached at equal distances by means of a suitable length of an endless rope. When the wheel is turned all the buckets coming up will be full of water while the buckets on the other side of the wheel would be upside down and empty, having discharged their water in a suitable trough from which it is drained out (see Fig. 4; Pl. IV). The wheel is usually rotated by a suitable gear worked by bullocks. In deep mines which attain a depth of from 50 to 70 feet and which happen to be very wet it would be advisable to use centrifugal pumps. In two workings in the Shahidan field centrifugal pumps were employed in the season 1925-26 and 1926-27.

In large pits steps are cut in the walls to enable the miners and other labourers to go up and down the mine with ease (Fig. 2; Pl. II). In the case of a small pit, ingress and egress to it is provided through a narrow specially constructed incline which is usually open but which in the case of deep pits is usually in the form of a tunnel. The excavated material is carried to the surface by men, women and boys who either pass it from hand to hand or carry it individually in small baskets. The rubbish is dumped anywhere near the surface of the mine or if there be an old mine close by, the debris is thrown in it with the result that the mines present a very confused appearance. The tools used by the miners are ordinary jumpers, picks and phowrahs.

The shales and sandstone bands as a rule do not present any great obstacle but in some of the large pits the large boulders occurring a few feet below the surface have to be broken by blasting them with a charge of gun-powder. Nitro-Explosives have never been used so far in any of the Panna diamond mines. Some of the bottom beds of sandstone are very hard as is also a sandstone band which occurs between the conglomerate and the Kakru in the Chunha mines about which mention will be made later.

After the removal of the conglomerate from the pit, the miners as a rule drive galleries in different directions to remove as much conglomerate as possible from underneath the walls of the pit. The conglomerate bed is exposed by the removal of the shales and is then worked in the usual way. If the roof of the gallery needs support badly it is propped up by a few pieces of timber.

Treatment of the diamond-bearing ore.

The methods at present employed for winning the diamond from its ore are quite primitive. The ore as it comes out from the mines is stacked in heaps. The crushing and washing operations are undertaken after the monsoon has properly set. The ore is crushed in large circular pits about 6 feet in diameter by about 4 feet deep specially sunk in the ground. The conglomerate is usually broken by two men equipped with sledge hammers who stand in the pit and deliver the blows one after the other. The operation of breaking is continued till all the ore is crushed to fragments of the desired size. To prevent any diamonds from flying away the pits are in some cases covered with thatched roofs. The crushed ore is washed in rectangular pits specially excavated in the alluvial soil for this purpose. They are lined with slabs of sandstone to prevent admixture of clay during the washing process. The pits are half covered with ore and then filled up with water. To separate the particles of clay and mud adhering to the crushed material one or two men stand in each of the pits and swirl up the mass vigorously. When the crushed stuff is thoroughly freed from mud it is removed from the pits in bamboo baskets. Besides the rectangular pits a few circular pits are also sunk in the alluvium; these are also lined with flaggy sandstone. These circular pits are filled with clean water and the baskets are dipped in the pit with a swift downward movement and as swiftly lifted out of it. This process is continued till the crushed stuff is quite clean. During the operation of dipping and lifting the basket a swirling movement is also imparted to the stuff contained in it. To remove the final traces of mud the material is washed with clean water poured over it from an earthenware vessel. The washed stuff is then spread on a clean and smooth piece of ground where it is allowed to dry and is then carefully searched for diamonds. When one party has finished searching, the treated material is again spread out and searched by a second batch of workmen so that no diamond may escape notice. (Figs. 12-14-16).

No sifting of any sort is resorted to which is a great drawback to the successful treatment of the ore. The only sorting that is practised consists in rejecting and throwing away large pebbles and boulders of the unproductive stuff prior to the final crushing of the conglomerate.

CHAPTER II.

SHAHIDAN GROUP OF MINES.

The present day diamond workings in the Shahidan area proper are situated at a distance of one mile and a quarter to the E. N. E. of the first milestone on the Panna-Bisramganj road. The output of these mines during the last 11 years was 2,400 ratis while the total output of diamonds from all the mines in the Panna States was 4,427 ratis. It is therefore clear that more than half the total output of diamonds was from the Shahidan mines. Under the head of Shahidan mines the following may be grouped:--

Shrinagar .. Pukhri ..	Not worked at present.
Chunha .. Karra .. Ogra .. Shahidan ..	Worked at the present day and known collectively as Shahidan mines.

General Description.—The Shahidan mines have long been known to be the best diamond-producing centre in the whole of Panna State. The quality of the diamonds produced from these mines is good, the size of the diamonds is larger than in the other mines and the yield per cubic foot is also greater than from workings in other parts of Panna. Shahidan must have been a very active diamond mining area in the past as Capt. Franklin, Jacquemont, Rousselet and many others have described these mines. During the minority period of the present Ruler of the State these mines were worked on a small scale. Since 1916 these mines have been regularly worked every year.

PLATE III.

Photo by K. P. Sinor.

FIG. 3.

Photograph of a pit in the Shahidan area showing a very characteristic V-shaped fold which is filled in with gravel and boulders from the layer resting on the top of the green and red Jhiri shales.

In the appendix will be found statements of the production of diamonds at the Shahidan mines for the period July 1916 to December 1929.

Geological formations met with in the Shahidan group of mines.

As has been stated before, the diamond-bearing conglomerate occurs in between the Panna shales (also known as the Jhiri shales) and the Upper Kaimur sandstone. The Panna shales lie above the conglomerate while the Kaimur sandstone rests below it.

The following section was observed in Heeralal Dhami's mine which was excavated in the working-season November 1926 to May 1927 :—

Nature of formation.	Thickness.	Total depth from surface.
Soil containing a number of rounded boulders of sandstone (Fig. 5.)	14-0	14- 0
Disturbed shales showing peculiar V-shaped folds with their apices pointing down (Fig. 3.)	4-0	18- 0
Alternating bands of chocolate-coloured and green shales with flaggy sandstone partings (Figs. 1 & 2.) ..	30-0	48- 0
Fine grained diamond-bearing conglomerate (*kakru*) ..	0-6	48- 6
Shaly parting (*gilta*)	0-4	48-10
Diamond-bearing conglomerate (*muddha*) containing large quartzite and Jasper pebbles	1-0	49-10
Kaimur Sandstone	..	..

The depth at which the diamond-bearing conglomerate is found in a mine depends on the position of the mine. The further a mine is from the outcrop the deeper it will have to be sunk to reach the conglomerate bed. The formations have a southerly dip. Those parts of the Shahidan field where the conglomerate was close to the surface have mostly been worked out. In the deep workings in the Shahidan area the conglomerate bed is at present found at a depth varying from 50 to 65 feet. Miners with a very small capital usually sink pits in Ogra and Chunha where the conglomerate occurs at a depth of 25 to 30 feet.

Result of unsystematic methods of working the mines.

The chief difficulty which is experienced at present in the Shahidan area is that no one can say with certainty whether a certain patch of ground is unworked (virgin) soil or whether it represents the site of an old mine which has since been filled up. The miners call the virgin ground "*jemada*" while the site of an old mine which has subsequently been filled by material excavated from other mines and by material transported through the natural agency of water is known as '*purao*'. Due to the unsystematic methods of mining which have been in vogue for years past the mines present a confused spectacle as there is not a single place in the partially worked out area where one can say with certainty that the conglomerate could be found in depth. Every year, the local miners sink a few new pits in this area. With luck one may strike an absolutely undisturbed area but more often than not the miners come across made-ground in which case they have to rest content with what little muddha may have been left unworked by the old miners.

This pernicious system of unsystematic mining has its repercussion in another direction also, which is that the water from the old workings at times rushes into the new workings if, by chance, one of the radiating galleries in an old mine (locally called *bogda* or *kullaua*) is struck. This has happened several times ; only recently, in April

PLATE IV.

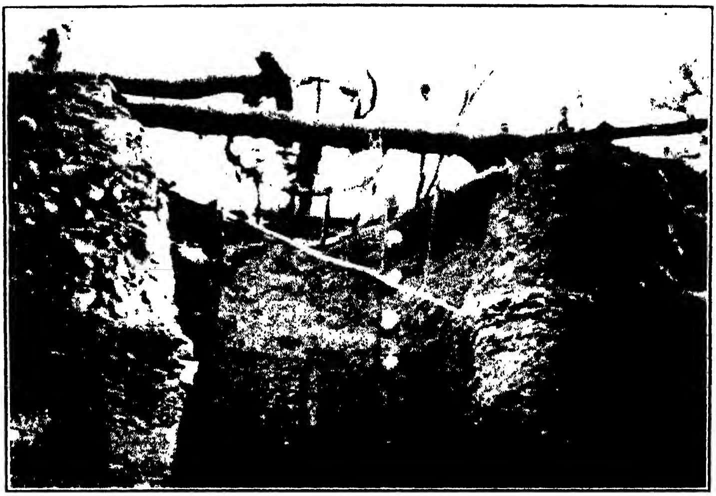

FIG. 4.
" Persian Wheel," a primitive contrivance which is used for unwatering the pits at Shahidan even at the present day.

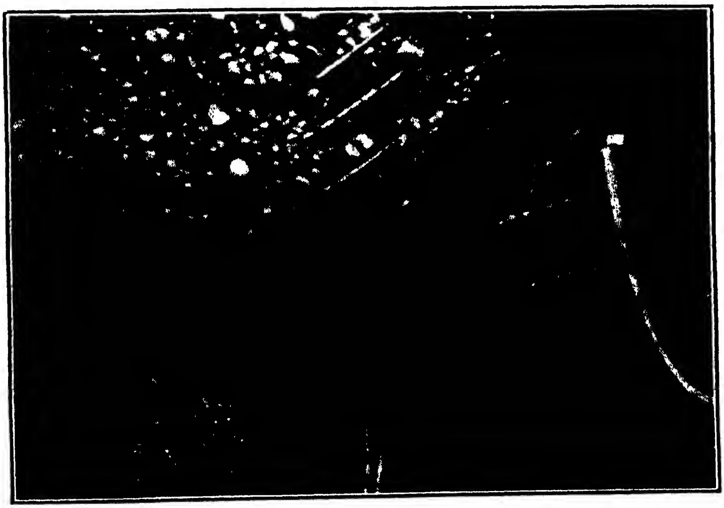

FIG. 5.
Part of a pit sunk by Heeralal Dhami in 1927 in Shahidan showing a V-shaped fold in the Jhiri shales. Rounded boulders occupy the trough of the fold. In the bottom left corner of the figure is seen a tunnel and in the top right hand corner there is a hole for draining out the water.

Photos by K. P. Sinor.

1927, in two very large pits, one sunk by the Rajputana Minerals Syndicate and the other by Heeralal Dhami, the influx of water was so great that the centrifugal pumps installed in those mines could not cope with it. (Figs. 2 & 7.)

The position of the conglomerate in the Shahidan group of mines.

The conglomerate occurs above the Upper Kaimur sandstone, and below the Panna shales. In the Shahidan field minor variations have been observed with respect to the exact position of the diamond-bearing bed. In many mines the conglomerate is separated from the shales above by a layer of *kakru* which is the term given by the miners to a friable conglomerate of fine grain. The term used by the miners for this particular kakru occurring in Shahidan is *ranjka ;* the kakru is in turn separated from the conglomerate proper, *i.e., muddha*, by a thin layer of shales which is known as *gilta*. Both *ranjka* and *gilta* are washed and treated for diamonds.

A fact which deserves special mention is the presence in some mines of a thin shaly band between the Kaimur sandstone and the coarse diamond-bearing conglomerate, *muddha*. It is the experience of old miners that when the *muddha* is separated from the Kaimur sandstone by a shaly layer the yield of diamonds from the conglomerate is not so large as when the conglomerate is in intimate contact with the sandstone. When the quartzite and jasper pebbles in the conglomerate are found actually embedded in and firmly cemented to the top surface of the Kaimur sandstone, the crop of diamonds yielded by the conglomerate is very rich.

In some parts of the Shahidan field there is no shaly parting (*gilta*) between the very coarse and the finer grained conglomerates. In other parts of the field, as at Chunha, the muddha is separated from the kakru by a flaggy bed of sandstone known as *chhaoni* from a foot to about 4 feet in thickness.

In the Shahidan area the conglomerate occupies one of the following four positions among the other beds :—

1	2	3	4
Green and red shales.	Green and red shales.	Green and red shales.	Green and red shales.
Kakru.	Kakru.	Kakru	Kakru.
Shaly parting (Gilta.)		Chhaoni	Shaly parting (Gilta.)
Muddha.	Muddha.	Muddha.	Muddha.
Kaimur Sandstone.	Kaimur Sandstone.	Kaimur Sandstone.	Shaly parting.
			Kaimur Sandstone.

Cases 1, 2 and 3 are hopeful from the point of view of the yield of diamonds. In case 4 there is not much hope of a very good crop of diamonds; at least such is the experience of old miners.

The composition of the coarse conglomerate, the finer grained conglomerate, the flaggy sandstone (Chhaoni) and the pebbles of jasper and quartzite associated with the conglomerate will be dealt with separately under the heading of petrographic notes.

I will now describe the different mines in the Shahidan field.

Shrinagar Mines.

The Shrinagar mines are situated to the north-west of the Shahidan mines proper. They must have been extensively worked in former years. From the records available it is found that they were worked in 1904-05 and later from August 1916 up to September 1919. Since then, these mines have not been worked. During three working seasons, *i.e.*, from 1916 to 1919, 85 diamonds were found, the total weight of the diamonds being 89 Ratis. In the Shrinagar area proper the coarse conglomerate does not occur, having been removed by the natural weathering and transporting agencies. The formation on the top of the Kaimur sandstone is a gravelly bed which has been derived from the muddha. Sometimes two bands of kakru occur, separated by an unproductive shaly layer. The chief productive layer is that of the gravel which rests immediately above the Kaimur sandstone. The upper layer of kakru has often been found to be unproductive. The depth of the pits is usually from 8 to 10 feet ; they are mostly sunk during the rains when a fair supply of water is available for the washing operations.

Pukhri Mines.

The Pukhri mines are situated to the west of Ogra and Shahidan mines. They have not been worked for the last 30 or 40 years. It is said that these mines had produced, in the past, some very good large diamonds.

Shrinagar surface workings.

The "Chhila" or surface workings in the Shrinagar area are situated on the eastern side of the Panna-Bisramganj road not far from the second milestone from Panna. Many of these workings lie on a tract parallel to the metalled road mentioned above. The diamond occurs in the disintegrated material produced by the weathering of kakru which very likely had outcropped in this part. Laterite pebbles abound in this area underneath a thin capping of alluvium. Being very easy to work, the surface of the ground in this part has been riddled with holes, small and large, over a considerable area. These mines are not worked at the present time. They are also called "Lallia" mines because of the red colour of the soil owing to the prevalence of laterite pebbles and boulders.

Chunha Mines.

The Chunha mines are situated to the north and north-east of the Shahidan mines. The mines are worked in the same way as at Shahidan. The formations met with at Chunha are similar to those of Shahidan; the only difference is the presence of sandstone layers (*chhaoni*) between the conglomerate and the kakru, varying in thickness from 1 to 4 feet. In the pits which I saw in 1927 the thickness of the *chhaoni* was about 2 feet. Nodules of carbonate of lime were found in many pits sunk in this area which probably accounts for the name "Chunha" given to the mines. The *chhaoni* is really a hard indurated sandstone which is run over by large and small tablets of whitish clay. Similar layers of hard sandstone in which clay pellets occur have been known to occur in some of the Shahidan mines also.

Karra Mines; Karra bore-hole.

The old workings at Karra are situated to the east of the Shahidan mines. Years ago this part must have been actively worked as is evidenced from numerous old pits and refuse heaps. There is a lot of virgin ground, *jemada*, close to Karra. With the object of proving the nature of the underlying formations in this part with a view to open out new workings in this area on a systematic basis a bore-hole had been sunk in this area under my supervision in 1927. The conglomerate bed was reached at a depth of 24 feet from the surface. Kaimur

PLATE V.

FIG. 6.
Section of a pit in the Shahidan mines showing folds in the top layers of the green and red Jhiri shales. The miners had opened out this pit only a fortnight before this photograph was taken.

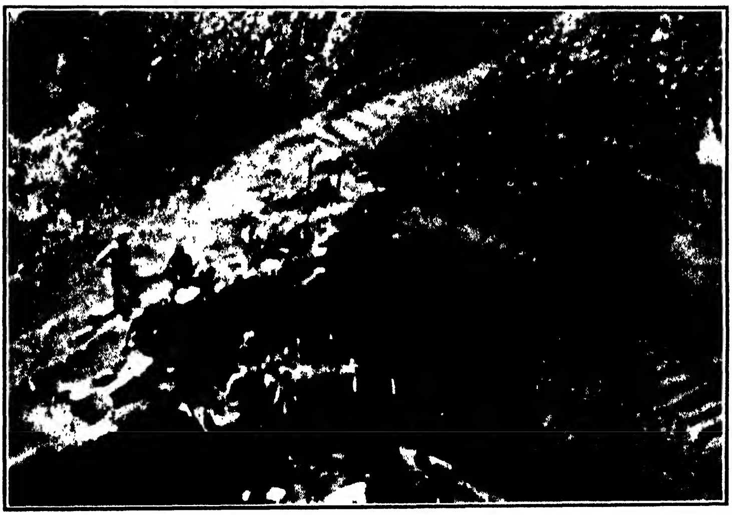

FIG. 7.
Another view of the pit sunk by the Rajputana Minerals Syndicate in 1927 shown in fig. 2.

Photos by K. P. Sinor.

sandstone was directly below it. The boring was continued to a total depth of 186 feet to see if there was a diamond-bearing bed in the Kaimur sandstone but none was encountered. From a depth of 24 feet 10 inches right up to the total depth, *viz.*, 186 feet 6 inches the formations consisted entirely of sandstone, the only differences being in the colour of the beds and their hardness; no noteworthy features were observed in the sandstone obtained from the bore-hole. The beds above the conglomerate consisted mostly of shales with a few sandstone bands. In the appendix a section of this boring is given.

Ogra Mines.

The Ogra mines known also as the Patparia Mines are situated to the north and north-west of the present day Shahidan mines. Both *kakru* and *muddha* occur in the Ogra mines same as in the Shahidan mines but, the *muddha* is not so compact as in the latter, having suffered more or less from disintegration. I have, however, seen some very hard and tough conglomerate on the exposed surface of the Kaimur sandstone in one particular part of this field. So compact was this conglomerate that the miners had to light fires on its surface repeatedly to loosen it from the sandstone and chisels had to be used to break the conglomerate. Though Kaimur sandstone is exposed in this field here and there, there are many parts which are covered by alluvium. As the conglomerate occurs in this field within easy reach of the surface, a large part of this field has been worked out. There are still some unworked areas, however, where the miners sink a few pits every year.

Shahidan Mines.

Shahidan is the most famous diamond field in the whole of Panna. The conglomerate from these mines has always yielded a good crop of diamonds. The average weight of the diamonds obtained from the Shahidan mines is somewhat over a rati. The only drawback to the successful exploitation of this field is that a lot of accumulated water in the old pits in this area occasionally finds its way in the new workings increasing the cost of pumping. Besides, the depth of the workings in Shahidan proper is greater than in any other part of the field as the conglomerate bed has a southerly dip. The depth at which the conglomerate was obtained from the pit sunk by the Rajputana Minerals Syndicate in 1927 was about 65 feet. (Fig. 2.—Plate 2.) The higher cost of pumping and the greater depth to which the pits have to be sunk prevent miners with scanty means from excavating pits in this area, though it is the richest from the point of view of yield and the size of diamonds obtained.

CHAPTER III.

GROUP OF MINES SITUATED CLOSE TO PANNA, EXCLUDING THE SHAHIDAN MINES.

Besides the famous Shahidan mines there are other diamond workings close to Panna. These are Ranipur, Bhawanipur, Nirandpur and Bhaironpur.

Ranipur and Bhawanipur Mines.

About six furlongs to the west of Panna town there is a large tank known as Kamlabai tank. Both Ranipur and Bhawanipur mines are situated close to this tank, the Ranipur mines being the name given to the workings north-west of the tank and the Bhawanipur mines to the diggings north-east and east of the tank. At the present day the Bhawanipur mines are the more important of the two. The latter have been regularly worked from 1916 to the present day and have yielded diamonds worth Rs. 40,136 from July 1916 to June 1927. These mines were also active at the time of Vredenburg's visit in 1904-1905. The diamond occurs in these mines in a layer of *kakru* which as explained before is the redistributed material derived from the weathered remnants of the muddha which must originally have been exposed to the north of the Kaimur dip-slope. This kakru naturally consists therefore of small laterite pebbles which largely occur in the alluvium and of waterworn fragments of shale and sandstone and of pebbles of the original conglomerate. In the Bhawanipur mines undecomposed conglomerate is occasionally found underneath the kakru, but in the Ranipur mines only the kakru is found beneath the alluvium. The depth of the pits naturally depends upon the thickness of the alluvium in that part. It is generally from 8 to 15 feet. Going towards Old Panna from the Bhawanipur mines I saw some small patches of conglomerate in the Kaimur sandstone exposed in the bed and on the sides of the Magda Nala. The Ranipur mines are being worked since 1924. During the 3 years from July 1924 to June 1927 these mines produced diamonds worth Rs. 2,307.*

Nirandpur Mines.

The Nirandpur mines are situated to the north of the Maharajsagar tank. They are easily accessible as the Panna-Bisramganj metalled road runs quite close to them. The diamonds are found in these mines in a disintegrated *muddha* covered by a layer of *kakru* which in turn is covered by green shales. There is another layer of lateritic *kakru* on the top of this, but this is not treated for diamonds. Vredenburg has described workings similar to this at a place known as Harduapur, but it seems that the name Harduapur has been changed to Nirandpur. These mines are very easy to work, it being necessary to sink pits only from 5 to 10 feet in depth in alluvium and shales. This field has now become a great favourite with miners who have not much capital to spend. The yield of diamonds from these mines during the year from July 1925 to June 1927 was 74 weighing 71 rati and 11 biswa which were sold for Rs. 6,130.

Bhaironpur Mines.

The Bhaironpur workings are situated in the gorge of the Mahou river about 1½ miles to the north of Old Panna.

* During the six months from the 1st July 1929 to 31st December 1929 the Ranipur mines produced diamonds valued at Rs. 7,929. (See Table 9, Appendix).

CHAPTER IV.

THE RANJ RIVER GROUP OF DIAMOND MINES.

The following mines have been grouped together as they are situated in the part watered by the upper reaches of the Ranj river and its tributary streams :—

Kalianpur.
Ganeshpur.
Radhapur.

Kalianpur Mines.

Kalianpur, which is situated about 4 miles to the north-east of Panna, was famous for its conglomerate workings as also for its alluvial workings once upon a time. That the extent of the diamond mines was very large can be seen from large heaps of boulders which stretch for nearly a mile in a more or less north-west to south-east direction. Whether these heaps of water-worn boulders, large and small, represent the site of the old alluvial workings or the conglomerate workings is a moot point, as these mines were abandoned years ago. A bore-hole was put down at a place not very far from the village. The section revealed by the bore-hole is as follows :—

KALIANPUR BORE-HOLE.

Nature of formation.	Thickness.		Depth from surface.	
	Feet.	Inches.	Feet.	Inches.
Alluvium	16	0	16	0
Chocolate shale	11	6	27	6
Green shale, hard	5	2	32	8

Nature of formation.	Thickness.		Depth from surface.	
	Feet.	Inches.	Feet.	Inches.
Sandstone, hard, greyish	3	8	36	4
Green shale, hard	2	0	38	4
Chocolate shale	1	0	39	4
Hard quartzitic sandstone	2	3	41	7
Chocolate shale	12	11	54	6
Green shale	5	6	60	0
Sandstone, greyish	2	0	62	0
Hard saccharoidal sandstone with clay pellets in lower part	3	10	65	10
Diamond-bearing conglomerate	0	3	66	1
Hard sandstone	16	11	83	0
Sandstone stained with iron-oxide	0	8	83	0
Hard white sandstone	5	0	88	8
Brownish sandstone	0	4	89	0
Hard white sandstone (Kaimur)	19	0	108	0

The bed of conglomerate proper occurs at a depth of 65 feet 10 inches from the surface. It is very likely that there is about 6 inches of the diamondiferous conglomerate on the top of this as was revealed by clay pellets.

It will be observed from the above section that the position of the conglomerate at Kalianpur is somewhat different from that at Shahidan inasmuch as there are about 6 feet of hard sandstone between it and the lowest shale bed whereas at Shahidan the conglomerate occurs directly above the Kaimur sandstone or occasionally with a few inches of shale or flaggy sandstone intervening between it and the upper Kaimur sandstone. It may be mentioned, therefore, that the further east we go from Shahidan and Chunha the mining of the conglomerate by the system which is at present in vogue would be more and more difficult as there are very hard bands of a grey sandstone between the shales and because of the 6 feet or more of sandstone which occur between the conglomerate and the shales. How the old miners worked this conglomerate bed is a puzzle to me ; they probably worked considerably further towards the north of the village where the thickness of the formation above the Kaimur sandstone would be less owing to the southerly dip of the strata.

Thickness of the conglomerate as revealed by bore-holes.

Regarding the insufficient thickness of the conglomerate as revealed by borings not only in this but other areas I should make it quite plain that no great importance should be attached to it as the conglomerate does not rest on perfectly horizontal beds of Kaimur sandstone with the result that in some parts a boring may show a poor thickness and in others a greater thickness. All that the boring shows is the actual horizon at which the conglomerate occurs and the sequence of the associated beds. There is another point to remember, which is that in a coarse conglomerate such as that which occurs at Shahidan there are occasionally patches which are more like sandstone in character though belonging to the conglomerate bed proper. If a boring happens to pass through such a patch with considerable sandy matrix the cores would not show the regular characteristics of a conglomerate but of a sandstone invaded in parts by clay pellets. It is thus that clay galls and pellets are useful as indicating the presence of a diamondiferous bed in the immediate vicinity. In nearly all the prospecting bore-holes put down in Panna State tools $2\frac{1}{2}''$ in diameter were used which gave cores $1\frac{1}{2}''$ in diameter. I have seen on many an occasion large pieces of conglomerate taken out from the mines with barren patches consisting mostly of sandstone matrix. If a bore-hole happened to be vertically above such a patch it would only show the characteristics of a sandstone invaded here and there by clay tablets.

Ganeshpur, Radhapur and Sonhara workings.

The Ganeshpur diamond mines are situated on the left bank of the Ranj river to the south-east of the old Kalianpur workings. The pits sunk there have to penetrate from 12 to 18 feet of alluvium before kakru is met with. The layer of kakru is found resting on the green and chocolate coloured shales and is worked in the usual way described before.

Radhapur workings which are situated on the right bank of the Ranj river are similar to those of Ganeshpur. Neither of these mines is worked at present.

Sonhara is situated at a distance of a mile and half due south of Kalianpur. The village is at the base of the slope of the Upper Rewa sandstone scarp. There are old surface or *chhila* workings in this part which indicate its former mining activity. When I first visited Sonhara many local men evinced a keen desire to reopen the mines if the State would permit them to do so. I would however like to see the old Udesna workings which are only three miles to the South of Sonhara to be first opened to the public as they are of much greater importance than shallow or surface workings.

CHAPTER V.

KODAIA GROUP OF MINES.

Kodaia is about 4 miles to the north of Panna, close to the Panna-Bisramganj road. The former workings are situated in a large area, about one square mile in extent with Kodaia as the centre. The mines are not worked at the present day. Refuse heaps of washed *kakru* from which diamonds have been picked out at one time or other are the only signs of its previous activity. The old workings in this area were detrital in character. In the old refuse heaps I did not see any trace of *muddha*, either compact or weathered, though, according to Vredenburg, the old miners worked both the upper layer of kakru as also the lower bed of friable and weathered conglomerate. All the old pits have been filled in, partly by debris and partly by alluvium. The geological formations round about this area consist of Upper Kaimur and Lower Kaimur sandstones covered with alluvium. Shaly fragments were present in the rubbish and refuse heaps, as also laterite and other pebbles which usually occur in the kakru.

Bardhai Mines.

About two miles to the north-east of Kodaia, to the east of the Bisramganj road there is another site of old workings known as Bardhai mines. The workings in this area seemed to be of the same kind as those at Kodaia. The formations here consist of Lower Kaimur sandstone covered in part by alluvium. Wherever alluvium was found on the surface it was excavated and the layer of kakru extracted therefrom. Even the gravel which had been deposited in between the crevices of the sandstone used to be worked and treated for diamonds, such workings being known as *junji* workings in the vernacular. Quite a large area seems to have been worked out in former times but no one remembers at the present time whether the yield of diamonds from these mines was good or otherwise. The workings in this area were all shallow, known as *chhila* workings.

Shikarpur, Bahadurpur and Kishorepur workings.

Further to the south-east of Kodaia there are some very old workings known as Shikarpur, Bahadurpur and Kishorepur Mines. These also were essentially detrital workings.

CHAPTER VI.

WORKINGS IN THE NEWER CONGLOMERATE.

As stated before, there are two diamondiferous horizons in Panna State, one belonging to the lower division of the Upper Vindhyan in which all the mines which have so far been described occur. The other is situated at a higher level, both topographically and geologically, in the Upper Rewa sandstone plateau overlying the sandstone. Of the mines in this upper horizon, I will first describe the Sakeria and Udesna mines. The diamond-bearing ore has not been seen *in situ* by any of the previous visitors to the mines in this area nor have I have been fortunate enough in finding it. There is, however, every reason for believing that at a somewhat higher horizon than that in which the old workings in this area are situated there must have been a diamondiferous conglomerate, the weathered remains of which found their way in these workings. The chief difference therefore between the Panna, Kodaia, Itwa, Barghari, and Bijepur mines on the one hand and the workings which I am about to describe on the other, is that whereas in the former the diamond ore consists of the original conglomerate as also the derived conglomerate and gravel, in the latter the derived gravels form the only workable ore, the original conglomerate not having been found anywhere up till now. This new conglomerate from which the diamondiferous material occurring in all the mines in this area has been derived may therefore aptly be termed the Upper Rewa conglomerate as its position must be somewhere between the Upper Rewa sandstone and the Bhander shales overlying it. The diamond-bearing material could never have been derived from the Lower Rewa conglomerate as the topography of the two beds precludes such a possibility. As all the mines in this area are lying dormant at the present day it has not been found possible to trace the original newer conglomerate *in situ* but it seems certain that when these workings are opened the original conglomerate would be found.

Extent of the Workings in the Newer Conglomerate.

The workings connected with this Upper Rewa conglomerate extend from near Sakeriya (which is 8 miles to the North-East of Panna) to Singpur and Matain in Panna territory, a distance of about 20 miles. Outside of Panna territory the workings in the newer conglomerate extend as far as Kothi and Naogaon. These workings are all situated in a belt which runs in a S. W. to N. E. direction same as the workings in the older conglomerate. The old diggings at Sakeriya are of the kind previously described as *chhila* workings. The diamond-bearing kakru rests immediately on the Upper Rewa sandstone beneath a thin capping of alluvium. It is this layer of gravel which used formerly to be worked at Sakeriya. No workings are in progress at the present day and as the mines were closed years ago there are not many indications of their former activity.

Medlicott described the Sakeriya workings in the Memoirs of the Geological Survey of India, Vol. II, p. 73. Vredenburg's description of these mines appears in the Records of the Geological Survey of India, part 4, 1906. A description of the Sakeriya mines also appeared in the N. W. Provinces Gazetteer, 1874, p. 565. This was quoted from "Pogson's Boondelas" and runs as follows :—

"The diamonds are found below a stratum of rock 15 to 20 feet thick which takes the native months and even years to cut through with their chisels, the rock being rendered friable by lighting fires upon it."

While it is true that the rock formations at Sakeriya consist of hard quartzitic sandstone it may be mentioned that no conglomerate occurs in it. I am in a position to say this emphatically as a bore-hole put down quite close to the village for a tube-well did not reveal any trace of a conglomeratic layer not only within a depth of 20 feet but for the matter of that even at a much greater depth. The total depth attained by this bore-hole was 240 feet. Besides, an admirable section of the formations up to 55 feet from the surface can be seen in a very large well the work on which had been started years ago and which was completed only a few years back. It is because this well goes dry during the summer months that I was asked by the Panna Durbar to put down a tube-well close to the village. If, as stated in Pogson's "History of the Bundelas", the diamonds are found underneath this hard rock at a depth of from 15 to 20 feet the diamond-bearing formation would certainly have been met with during the process of sinking the well.

Medlicott has confused the Sakeriya workings with the alluvial workings at Udesna which he has really described.

Udesna Diamond Mines.

The Udesna mines also known as the Maharajpur mines were very famous once upon a time. The mines are situated one and a half miles due north of Sakeriya in a very narrow gorge which extends for more than a mile. One very characteristic thing which I noticed at these mines was the great prevalence of saccharoidal quartz boulders and pebbles in the refuse heaps and also of quartz gravel in the debris of the washed kakru. These mines have ceased working since a long time. When Medlicott visited this place, the workings were in progress. The following is his description of the diamond ore then obtained from these mines :—

"The matrix here which consists of pebbles and boulders under an irregular thickness of yellow clay containing both kunker and laterite does not require to be broken up, the clay being separable readily by washing but the yield is not so certain as in the old conglomerate. There is a variable depth of clay, the middle third being kunkery and the lower lateritic. Below this the clay becomes charged with gravels, pebbles, and boulders, these rapidly increasing in size to great angular blocks of sandstone scarcely removed from their original beds. It is from between these that the best stuff is got, a stiff unctuous clay with quartz gravel in it. These workings are purely alluvial in character."

Tindini, Durgapur, Matain and Nibasta Mines.

Other localities where *chhila* workings similar to those at Sakeriya were carried on in the newer conglomerate are Tindini and Motwa near Shiorajpur, Matain and Markani near Singpur, and Durgapur and Nibasta between Shivrajpur and Singpur. Of these, I have seen the workings between Shiorajpur and Tindini known as Gazipur mines about a mile and a half to the north-west of Shiorajpur; also, the Durgapur mines which I reached from Singpur returning *via* Shiorajpur. I thus had the opportunity of seeing the whole of the tract between Shiorajpur and Singpur. The formation which is exposed in these parts is invariably the Upper Rewa sandstone which is in parts covered by a sufficient capping of alluvium to preserve the gravel bed in tact. These are the places which have been invaded by the old miners. From some old residents of Shiorajpur I was able to glean the fact that the Gazipur mines close to Shiorajpur used to yield a fair number of diamonds every year when the workings were in progress there. The *kakru* in these parts invariably contains some laterite pebbles.

Urdana and Karwani Mines.

Other mines in the newer conglomerate are those of Urdana and Karwani which I reached from Itwa after crossing the Rewa scarp. One thing which struck me particularly when I visited these mines was the very large area over which the *chhila* workings were scattered. It is a great pity that there are no old records in the State to show the yield from the different mines in former years as the information obtained from such records would have enabled one to spot out the richer and more promising areas. It seems to me that mines like those of Urdana and Karwani were worked many years ago as none of the inhabitants in those parts could supply any information regarding the old workings. They do not seem to have been worked within the memory of any living man.

Possibility of finding rich diamondiferous areas in other river gorges which cut the Rewa scarp.

Gorges similar to that of Udesna cut the Rewa scarp in many places between Sakeriya and Karwani. There is one about a mile to the east of Bikrampur. One-half of this gorge is within Panna territory, the other half belonging to Charkhari. Similarly, there is another gorge about a mile and a half to the East of Bilha. The Eastern part of this gorge is situated within Panna territory. There is another long and narrow gorge, longer even than the Udesna gorge, the narrow end of which is between Urdana and Karwani. These, in my opinion, are likely to contain diamonds if a systematic search were made for them. That the old miners did not work these places does not seem to be any reason for supposing that there are no diamonds in them. There were so many other accessible places that the old miners did not think it worth their while to open them out. I would particularly recommend trial workings to be opened out in the gorge between Urdana and Karwani as diamonds were found at both these places and as the diamondiferous material must naturally have found its way in the gorge through the numerous streams and streamlets which drain that area. The configuration of this gorge is very favourable for retaining any diamonds which may have been washed into it from the higher levels. This gorge resembles in outline the gorge of the Baghen valley leading to Kalinjar.

CHAPTER VII.

BAGHIN RIVER GROUP OF MINES.

Itwa Diamond Field.

Next in importance to the Shahidan Diamond Field is the Itwa diamond field. Itwa is 13 miles to the north-east of Panna as the crow-flies. Barghari, Maharajpur and Bijepur are all close to Itwa and all the four places are diamond-producing centres. These mines are situated between the hills forming the Upper Rewa sandstone escarpment whose general trend in this part is E.N.E. to W.S.W. and the Upper and Lower Kaimur sandstone hills to the north of the escarpment. These mines may be said with propriety to belong to the Baghin valley group, as the area in which they are situated is watered by the Baghin river and its tributaries. Other mines in the locality are those of Birjpur, Gehra and Bhimpahar situated from 3 to 6 miles further north-east of Itwa. I shall describe the different mines in the following order: Itwa, Barghari, Maharajpur, Bijepur, Birjpur, Gehra and Bhimpahar.

Itwa Mines.

The mines which are worked at the present day in Itwa are all alluvial in character but many years ago mining was carried on in the regular conglomerate bed which in this part occurs below a sandstone bed which does not belong to the Upper Kaimur sandstone but which occurs as a subsidiary bed in the Itwa shales. The conglomerate occurs underneath the sandstone and above the greenish and chocolate coloured shales whose aggregate thickness was found to be 58 feet near Itwa. Four borings were put down at Itwa and one at Bijepur. The sections thus obtained clearly show the relationship of the different beds. Vredenburg and some of the previous observers believed the thickness of the sandstone bed under which the conglomerate occurs to be about 20 feet but the borings prove that this bed is not more than 7 feet in the neighbourhood of Itwa and Bijepur. It may be said that this sandstone bed is similar to the sandstone bands which occur in the Shahidan area but represents a more developed formation.

The diamonds are obtained, at the present day, in Itwa, from a gravel bed which occurs at a depth of from 20 to 40 feet from the surface. I have seen pits as deep as 30 feet in Itwa. The diamondiferous gravel consists of pebbles derived from the older conglomerate together with laterite pebbles which are a characteristic feature of the gravel bed. The mining methods are primitive and similar to those followed in the Shahidan mines. At Itwa, however, there are no boulders nor are there any flagstone beds. Mining at Itwa is therefore not so expensive as mining at Shahidan. Usually the water is removed from the pits in earthenware vessels which are passed from hand to hand. Sometimes the pits are dewatered by a crude device in which a bucket or an earthenware vessel is attached to the long end of a bamboo suspended on a wooden fork which serves as the fulcrum, the short end of the bamboo being weighted with some stiff clay.

The kakru is treated for diamonds by being first churned up in a shallow pit specially sunk in the ground. In this process the pebbles are separated from their matrix.

The gravel is then put in bamboo baskets which are dipped in another pit full of water and swirled round to wash out all the mud. The gravel is then finally washed by pouring clean water over it and spread on a piece of ground specially cleaned and made smooth where it is searched for diamonds.

The average weight of the Itwa diamonds is less than that of diamonds obtained from the Shahidan mines. At the same time, the cost of mining the diamond-bearing gravel and of concentrating and treating it is not so great as in the case of the Shahidan conglomerate. The Itwa workings therefore yield a good return to the miners.

Unsystematic methods of workings.

I may mention here incidentally that the workings in the Itwa field present the same confused appearance as at Shahidan due to the haphazard mode of working which is prevalent there. I tried to induce the miners to put down pits to the south of the worked out area in a systematic fashion and pegged out a few claims but none of them was willing to work even a few yards away from the old workings. They prefer to work round and round their old claims rather work in a new place. Unless therefore unsystematic workings be stopped by a regulation I am sure that the miners will continue to work in their own way. As it is the intention of the Panna Durbar to induce the local men to revert to diamond mining as in the past it was not thought advisable to impose any restrictions at the present stage. As soon as diamond mining has been fairly revived it will be essential to enforce systematic working by stringent regulations.

The following is a section of the bore-hole put down at Itwa near the part where some conglomerate had been worked many years ago :

Section of Itwa Bore-hole No. 2.

Section of Itwa bore-hole No. 2.

	Nature of formation.	Thickness of formation.	Depth from the surface.
		Ft. In.	Ft. In.
	Surface soil	7 6	7 6
	(*a*) Sandstone (Lower Rewa)	7 0	14 6
Itwa Shales.	(*b*) Green shale	5 6	20 0
Itwa Shales.	Chocolate shale	4 0	24 0
Itwa Shales.	Green shale	0 6	24 6
Itwa Shales.	Chocolate shale	5 6	30 0
Itwa Shales.	Green shale	0 6	30 6
Itwa Shales.	Chocolate shale	2 0	32 6
Itwa Shales.	Green shale	1 0	33 6
Itwa Shales.	Chocolate shale	18 2	51 8
Itwa Shales.	Hard greenish shale	0 6	52 2
Itwa Shales.	Chocolate shale	9 0	61 2
Itwa Shales.	Green shale	2 0	63 2
Itwa Shales.	Chocolate shale	0 2	63 4
Itwa Shales.	Hard green shale	1 8	65 0
Itwa Shales.	Chocolate shale	1 0	66 0
Itwa Shales.	Green shale	3 0	69 0
Itwa Shales.	Chocolate shale	3 0	72 0
	Sandstone, greenish	0 2	72 2
	Sandstone, white, Upper Kaimur..	5 0	77 2
	Total depth from surface ..	77 2	

Although no conglomerate was found in this particular bore-hole the horizon where the conglomerate occurs is between the sandstone marked (*a*) in the section and the shale marked (*b*), as revealed by two other bore-holes. I was informed by some of the old miners that in the old conglomerate workings the pits were sunk to a depth of 5 or 6 feet more than the depth at which the conglomerate bed occurred. The shale from beneath the conglomerate was then excavated and the conglomerate was then worked by a method analogous to overhand stoping. I was told that the same procedure was followed at Bijepur also where conglomerate used to be worked in the past. The following is a section of bore-hole No. 3 put down at Itwa :—

Section of Itwa bore-hole No. 3.

	Nature of formation.	Thickness. Ft.	Thickness. In.	Depth from surface. Ft.	Depth from surface. In.
	Alluvium	4	0	4	0
Lower Rewa sandstone group.	Fissured sandstone	5	0	9	0
	Soft clayey stuff	0	6	9	6
	Sandstone, flaggy	0	10	10	4
	Diamondiferous conglomerate.	0	5	10	9
	Sandstone, flaggy	0	10	11	7
Itwa shales.	Green shale	3	5	15	0
	Alternate beds of green and chocolate coloured shale.	28	0	43	0
	Total depth ..	43	0		

It will be seen from the above that the horizon of the conglomerate bed is between the Lower Rewa sandstone (*a*) and the green shale (*b*) belonging to the Itwa group. Sections of bore-holes No. 1 and No. 4 put down near Itwa will be found in the Appendix.

Barghari Mines.

Barghari is situated two miles to the north-east of Itwa. Formerly, the conglomerate used to be mined at Barghari but the mines were abandoned many years ago. About a 100 yards to the east of the old workings there is a stream known as Chahchaia, in the bed of which some conglomerate can be seen *in situ*. The Barghari mines were reopened to the public in the year 1928 and the promising yield of diamonds obtained from some of the workings augurs well for the future of this field. I had pegged out 21 claims in January 1928 to the South-East of the old workings in an area which seemed to be undisturbed and which evidently looked like "*jemada*" or unworked ground. Out of the 21 claims conglomerate was found in 8 claims only.

As the occurrence and distribution of the conglomerate was not found to be uniform it was thought advisable to put down a few shallow bore-holes not very far from the old workings. Five bore-holes were sunk of which the third happened to be on made-ground. The other four borings revealed the following sections :—

No. 1 Bore-hole, Barghari.

	Ft.	In.
Alluvium ..	5	0
Kakru ..	0	4
Alluvium ..	0	8
Sandstone ..	13	6
	19	6

No. 2 Bore-hole, Barghari.

	Ft.	In.
Alluvium ..	15	0
Sandstone ..	5	0
	20	0

No. 4 Bore-hole, Barghari.

	Ft.	In.
Alluvium ..	10	0
Sandstone ..	12	0
	22	0

No. 5 Bore-hole, Barghari.

	Ft.	In.
Alluvium ..	8	6
Sandstone ..	5	6
	14	0

PLATE VI.

FIG. 8.

Mining the five-foot bed of conglomerate which occurs at the Barghari mines under a very thin capping of alluvium.

FIG. 9.

Mining the conglomerate at Barghari. The thickness of the conglomerate bed is 2'-6" in the claim shown.

Photos by K. P. Sinor.

The section as revealed in claims 8 to 14 in which conglomerate was found was as follows :—

	Thickness.
Alluvium	8 to 10 feet.
Sandstone	2 to 3 ,,
Conglomerate	2 to 2½ ,,
Sandstone	Underlying the conglomerate (not worked).

No conglomerate was found in any of the borings mentioned above nor was it found in many of the claims. Those miners who did not find any conglomerate in their workings moved further S. E. from their old claims and commenced working near the Chahchaia stream. Most of them found the conglomerate under a very thin capping of alluvium. In two new claims the thickness of the conglomerate bed was 5 feet.

Anomalous position of the Barghari conglomerate.

In Barghari the conglomerate appears to occur in two different horizons. In the case of claims 8 to 14 the conglomerate bed was found at a depth of from 10 to 13 feet below the ground level whereas in claims further S. E. it was found almost at the surface. In the first case the conglomerate bed was overlain by sandstone and also underlain by it (see Fig. 9). In the new claims the conglomerate occurred near the surface under about a foot or two of surface soil and it was underlain by sandstone. The level of the ground in the case of claims 8 to 14 is about the same as that of new claims nor are the strata dipping towards the north-west. The occurrence of two beds of conglomerate one at a higher level than another within a short distance of each other is rather peculiar. The total absence of conglomerate in other parts nearby is also very puzzling. A boring or two from 50 to 75 feet deep would elucidate the matter. It was my intention to put down such a trial boring at Barghari but the Panna Durbar wanted me to put down certain tube-well bore-holes. The trial boring could not therefore be put down.

Composition of the Barghari conglomerate.

The Barghari conglomerate has a sandstone matrix and consists of quartzite pebbles big and small, also jasper pebbles. A few clayey patches occur in it but the clay tablets which are so characteristic of the Shahidan conglomerate are conspicuous by their absence. Besides, there is very little clayey matrix in the Barghari conglomerate in which sandstone fragments predominate. Although many diamonds have been obtained from the conglomerate which has been mined and treated so far it appears that the size of the diamonds is much smaller than that of the Shahidan diamonds. This is probably because the Barghari conglomerate is not so coarse as the Shahidan conglomerate. It is, however, premature at this stage to pronounce a definite opinion regarding the size and quantity of the diamonds occurring in the Barghari conglomerate.

Maharajpur alluvial workings.

The Maharajpur alluvial workings are situated about half a mile to the north of Barghari, between it and Sirswahi. These mines have been opened recently. In 1928 about 15 pits were sunk in Maharajpur. The *kakru* occurs at a depth of from 15 to 25 feet under a thick capping of alluvium. The diamonds obtained from these mines are small but good in quality.*

Bijepur Mines.

Bijepur is about 3 miles to the west of Itwa. The Bijepur mines were worked many years ago as is evidenced by numerous old pits

* Small diamonds are obtained by washing the sand and garel occurring in the bed of the Baghen stream near Maharajpur. Such workings are known in the vernacular as "Bahonda" workings.

sunk in that area. The diamond occurs in the Bijepur field in a fine grained conglomerate similar to the conglomerate found on the top of the *muddha* in the Shahidan mines. From what I saw of the old workings I am of opinion that there must still be a lot of conglomerate in the unworked parts between the old pits. Moreover, there is a large area of unworked diamond-bearing ground also. In the old dumps one can see even at the present day both shale and stray pieces of conglomerate. To find out the thickness of the diamond-bearing bed and its depth from the surface a boring was put down in a large patch of apparently unworked ground in the old workings. Unfortunately no conglomerate was met with which seems very strange considering the fact that in all the adjoining old pits conglomerate was worked out as could be seen from the old refuse heaps. The absence of the conglomerate bed may be due to one of the two following causes. Either the conglomerate underneath the spot where the boring was put down was removed years ago by a tunnel from an adjoining mine or that the conglomerate bed had a tendency to peter out. I am more inclined to favour the first view because underneath the Lower Rewa sandstone a layer of soft, yellowish, clayey looking stuff was encountered. This is exactly at the horizon where the conglomerate bed should be. In bore-hole No. 4 at Itwa also the same thing had happened under a bed of Lower Rewa sandstone 7 feet thick there was a layer of about 6 inches of a clayey yellowish stuff which probably represents the area where the conglomerate previously occurred but which was worked out most probably by a tunnel. That this was the horizon at which the conglomerate occurred at Bijepur has been confirmed by old miners also who state that the pits were allowed to continue in depth in the Itwa shales and that the conglomerate was worked out by first removing the shales from underneath the sandstone and then breaking the diamond-bearing ore in a manner analogous to overhead stoping. The following is the sequence of formations in the Bijepur area as revealed by the boring :—

Bijepur bore-hole.

	Nature of formation.	Thickness.		Depth from surface.	
		Ft.	In.	Ft.	In.
	Alluvium	4	0	4	0
	Gravel	1	0	5	0
	Lower Rewa sandstone	7	0	12	0
	Soft yellowish clayey stuff.. ..	0	6	12	6
Itwa shales	Itwa shale (green)	8	6	21	0
Itwa shales	Chocolate shale	20	0	41	0
Itwa shales	Hard chocolate shale	2	0	43	0
Itwa shales	Chocolate shale	7	0	50	0
Itwa shales	Green shale	3	0	53	0
Itwa shales	Chocolate shale	6	6	59	6
	Upper Kaimur sandstone	3	0	62	6

It may be stated that the old Bijepur mines are situated only about a mile to the east of the celebrated Khamaria* workings. Franklin, Medlicott and Hacket have described the diamond workings at Khamaria and it may be pointed out that the Khamaria workings were considered to hold a very high rank and that the output of diamonds and the quality of diamonds produced in these mines were stated to be as good as those of Shahidan. It is only fair to presume that the same conglomerate which occurs at Khamaria also occurs at Bijepur as the two places are only a mile apart. The Khamaria diamond ore has been described by Hacket as a conglomerate sand-

* The Khamaria diamond mines belong to Charkhari State.

stone made up of pebbles $\frac{1}{8}''$ to $\frac{1}{2}''$ in diameter in a rather shaly matrix which also includes clay galls. The Bijepur conglomerate which I have examined is exactly similar in character to the above.

From two very old and intelligent miners at Itwa I was able to glean the fact that the Bijepur mines were famous once upon a time, that the yield of diamonds from these mines was large and that the diamonds were of good water. I strongly advocate the sinking of pits in this area departmentally or as an alternative course to allow local or Panna men to work the mines with a view to get further information regarding the sequence of formations, thickness of conglomerate, grade of conglomerate and the quality of the diamonds.

Birjpur Mines.

Two miles further to the north-east of Barghari lie the old Birjpur diamond mines. These mines had been visited by Medlicott. According to him there is a two-foot bed of clear conglomeratic sandstone, resting on pure sandstone beds, which was worked at the surface. He has stated in Memoirs of the G. S. of I. Vol. II. that he was puzzled regarding the position of this conglomerate. Early in 1928 I had visited Birjpur but as all the mines had been closed years ago and all the old pits had been obliterated no definite information could be obtained regarding the exact position of the conglomerate with respect to the Lower Rewa sandstone and the Itwa shales. I strongly recommend a boring from 50 to 75 feet deep in a suitable spot near the old mines. I also recommend a similar boring 50 to 75 feet deep near Barghari as its exact position is as much puzzling to me as the position of Birjpur conglomerate was to Medlicott. The position of the diamond-bearing conglomerate in the group of mines near Panna is between the Jhiri shales and the Upper Kaimur sandstone, the former overlying the conglomerate and the latter underlying it. Similarly the position of the conglomerate at Itwa and Bijepur is between the Lower Rewa sandstone and the Itwa shales, the former overlying and the latter underlying the conglomerate. At Barghari however in the actual workings it was found that the conglomerate is both overlaid as well as underlaid by the sandstone. I am not at all certain whether the underlying sandstone is the Kaimur sandstone or whether it is a continuation in depth of the Lower Rewa sandstone. If the underlying sandstone is the Kaimur sandstone then it is a clear case of the overlap of the Itwa shales. Two similar cases of the overlap of Itwa shales have been mentioned by Mallet in Vol. VII, Part I of the Memoirs of the Geological Survey of India on page 67, one at Kishengarh, and another further east of Babupur where the Lower Rewa sandstone has been known to rest directly on the Kaimur sandstone.

It may be mentioned that many promising sites in most diamond fields have been forgotten as mining was closed for a number of years. It is essential therefore to find out such promising areas by allowing the local men to work the mines in the different fields for one or two seasons. As soon as the necessary information has been obtained, mining may be restricted in the more promising areas.

Gehra and Bhimpahar Mines.

The Gehra and Bhimpahar mines are situated about two miles to the north-east of Birjpur. They are alluvial in character. The mines had been closed many years ago. At the time of my visit there some of the local men showed their willingness to work the mines if the State would permit them to do so.

PLATE VII.

FIG. 10.
Relief-weathering as seen in the Lower Rewa Sandstone exposed in the hills near Bhim Pahar. The rugose appearance of the rock surface has been produced by the unequal weathering of the different components of the rock.

FIG. 11.
There are many river gorges in the Upper and Lower Kaimur sandstone formations near Panna, Itwa and Majgawan. The illustration shows one such gorge situated about 1½ miles to the N. E. of Gahra.

Photos by K. P. Sinor.

CHAPTER VIII.

THE MAJGAWAN AGGLOMERATIC TUFF.

The mines to the west and south-west of Panna will be included in the Majgawan group of mines as the most famous mines in this locality are those of Majgawan and as they all lie close to the Panna-Majgawan fair-weather road. Majgawan is at a distance of 12 miles to the S. W. of Panna as the crow flies, the actual distance being about 17 miles. All the mines in this area with the exception of the Majgawan mines proper lie on the surface of either Upper or Lower Kaimur sandstone. The Majgawan workings proper differ from all other diamond mines in Panna State as the geological formations in which they occur are not the shales of the Lower Rewa division but an entirely different volcanic formation which may be called an agglomeratic basic tuff.

Both Capt. Franklin and Dr. Medlicott had visited these mines many years ago. According to Franklin, the infilling in the largest mine which he had seen in Majgawan on the occasion of his visit to that place was very peculiar. The mine to which he referred was most probably the famous mine known to the local men as "Bharakiran" the yield of diamonds from which was said to be very large. Although Vredenburg has included the Majgawan mines in the list of alluvial workings given by him on page 286 of the Records of the Geological Survey of India, Vol. XXXIII, Part IV (1906), he has not described the workings. It may be that he had not visited the mines or that he did not attach much importance to them as they were not worked in his time. Capt. Franklin describes the site of the large mine mentioned above to be in a huge basin, like an inverted cone, 100 yards wide and about 100 feet deep. He says, "Two-thirds of the basin are filled with a green mud containing a calcareous matter and with a thick covering of calcareous tuff. The diamonds occur in the green mud and the natives whose appliances do not admit of their going below a depth of 50 feet say that the diamonds become more abundant as a shaft descends." Medlicott has summed up his impressions regarding the Majgawan mines in Memoirs of the Geological Survey of India, Vol. II, as follows :—

> "The filling-in is certainly peculiar; the structure is like coarse foliation, a net work of strings of calc-spar inclosing laminæ and small lumps of green clay. In the only hole I saw, they were working the yellow clay from the crevices of this; but the men told me that at a greater depth there are alternative layers of green mud and of its mixture with calc-spar in which diamonds are found."

He further says, "from the present abandoned state of the Majgawan mines one could never discover the vortex described by Franklin. There was but one shallow pit open. It is, however, possible from old workings to trace a small area bounded on three sides by a ledge of sandstone."

The above is all the information which one can get from the publications of the Geological Survey of India regarding these mines. I must confess, however, that the statements by Franklin and Medlicott have proved very useful. I first saw these mines in November 1926 when I was on a short visit to Panna. The rocks which I saw scattered about the old mine seemed to me also to be very peculiar. I was not at all sure when I first saw them whether they were sedimentary in origin or whether they belonged to a decomposed basic rock as they had been considerably altered. A more careful examination of the rock proved that it was really an agglomeratic tuff.

I had put down my first boring in Panna State at a place known as Janakpur midway between Panna and Kalianpur. I then decided to put down the second bore-hole at Majgawan; my reasons for doing so were firstly, that the old mine known as 'Bharakiran' was reputed to be very rich in diamonds and secondly because the formations revealed by the old mine as also by the smaller mines in the neighbourhood were very peculiar and quite distinct from all other diamond-bearing formations occurring in Panna State. From Franklin's description in which he says that two-thirds of the basin were filled with green mud I was inclined to think that the formations at Majgawan in depth were more like the diamond-bearing yellow and blue clays of South Africa than any other formation. I selected the site of the bore-hole between Inota and Majgawan close to a large well. A Calyx drill with 2½″ tools was used. As the top formations kept caving in, a 4″ Drive-pipe had to be driven to a depth of 40 feet from the surface. A casing-pipe 3″ in diameter was then driven to a depth of about 70 feet. Below that depth no casing-pipe was required as the formations did not give any trouble. When the bore-hole had reached a total depth of 242 feet it had to be stopped for want of more drilling rods. I would have wished the boring to continue to a much greater depth but circumstances were not very favourable and as there were many other bore-holes to be put down in other parts of the State the work there could not be resumed. The sequence of formations met with, as revealed by the bore-hole, is as follows :—

Section of Majgawan bore-hole.

Kind of formation.	Total thickness. Ft.	In.	Total depth from surface. Ft.	In.
Surface soil	3	0	3	0
Gravelly stuff	39	6	42	6
Clay	7	6	50	0
Decomposed agglomeratic tuff, basic (yellowish)	13	4	63	4
Hard siliceous band	0	3	63	7
Decomposed agglomeratic tuff	41	11	105	6
Dark coloured hard quartzitic band.. ..	0	3	105	9
Dark greenish agglomeratic tuff	4	3	110	0
Dark quartzitic band	0	4	110	4
Greenish agglomeratic tuff	1	8	112	0
Dark tuff impregnated with quartz and calcite	0	4	112	4
Agglomeratic tuff	17	4	129	8
Hard agglomerate band impregnated with silica	0	4	130	0
Agglomeratic tuff	27	6	157	6
Black shaly looking band	0	9	158	3
Agglomeratic tuff	57	6	215	9
Black band	0	3	216	0
Agglomeratic tuff	6	0	222	0
Agglomerate impregnated with silica ..	0	2	222	2
Tuff	16	10	239	0
Hard Band	0	2	239	2
Tuff	2	10	242	0
	242	0	242	0

It will be seen from the above section that following the top layer of soil 3 feet in thickness there was soft gravelly stuff up to a depth of 42′-6″ from the surface

PLATE VIII.

FIG. 12.
Washing the crushed diamond-bearing conglomerate previous to spreading it out for searching diamonds. The two men on the left are seen puddling the crushed conglomerate with their feet.

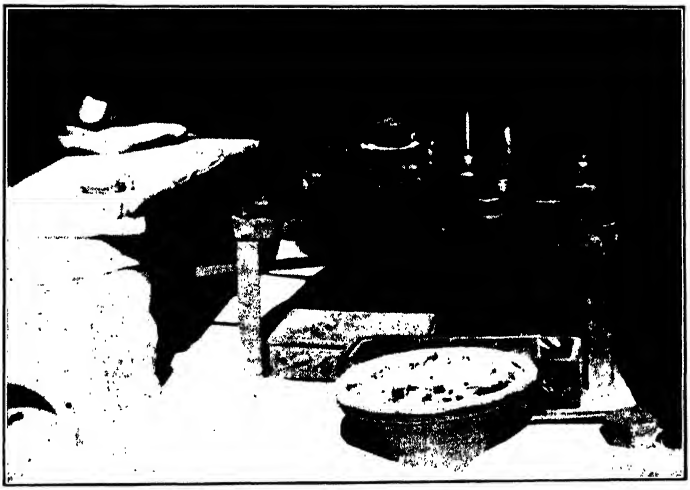

FIG. 13.
The diamond cutter's table.
The polishing wheel (skief) is rotated at great speed by a large wheel (not seen in the figure) which transmits its motion to the polishing wheel by means of a leather belt. Manual labour is used even at the present day in Panna for rotating the polishing machines though electric power is available.

Photos by K. P. Sinor.

which was underlain by 7′-6″ of clayey material. The gravelly stuff is nothing else but decomposed tuff. Under this there were 50 feet of dirty yellow agglomeratic tuff from which some cores were obtained as it was not so soft as the 50 feet of material above it. Underneath the decomposed yellowish tuff there is a dark greenish agglomeratic tuff over-run by strings and veins of calcite. This formation runs right up to 242 feet, *i.e.*, up to the full depth at which the boring was stopped.

It is evident from the above section that the greenish tuff occurs at a depth of about 105 feet from the surface in the particular part where the bore-hole was put down. At Majgawan proper the greenish tuff probably occurs at a somewhat higher horizon as at the time of Captain Franklin's visit the miners were excavating the "green mud" from the mine whose depth was stated by him to be 100 feet. I have carefully examined the cores under the petrological microscope and find that the yellowish tuff is in a more advanced stage of decomposition than the greenish tuff. The gravelly stuff 39′-6″ in thickness is nothing else but the yellow tuff in a disintegrated state as was ascertained from the cuttings and washings produced by the calyx drill. One peculiarity of the yellowish as also the greenish tuff is that when it comes in contact with water it soon crumbles and falls to pieces.

The most characteristic feature of some of the cores obtained is the presence of inclusions or xenoliths of older rocks. These vary in their nature. I have seen inclusions of fragments of white vein-quartz, red jaspidiceous pebbles, hard black quartzitic rock and even of standstone in some of the cores. A core of yellowish and more decomposed tuff revealed the presence of jet black inclusions somewhat tabular in form, which probably belong to the Semri shales. The hardness of these inclusions as also the presence of green chloritic material in them indicate that the rock had undergone a certain degree of metamorphism.

We shall now deal with the greenish tuff and with the associated hard bands consisting principally of silica, calcite, magnetite and decomposed greenish material. The hard bands were met with at different horizons, the thickness of the bands being from one inch to about four inches. The greenish tuff forms the bulk of the rock after a depth of about 100 feet. On a freshly broken face most of the cores of the greenish tuff show patches and fragments of a dark colour in a greyish or greyish green ground mass in which calcite veins and grains are scattered. Under the microscope the dark patches and fragments appear of a pale yellowish-green colour in thin sections, while the light greenish and greyish green mass does not allow much light to pass through. The greenish material on the whole is considerably in excess of the dark grains and patches which consist of altered olivine. When the tuff is smoothed and polished it appears very much like serpentine. In the serpentinous ground-mass idiomorphic outlines of olivine crystals are seen, the substance of the mineral having changed to a mineral very much like delessite or chlorophœite, and to serpentine. When thin sections were examined in ordinary light the crystals showed a fibrous texture and a pale yellowish colour. When the sections were examined between crossed nicols the fibres showed faint green, red and blue colours. Owing to the fibrous nature of the crystals no extinction could be observed when the stage was rotated because of the aggregate polarisation. These crystals which appear very much like chlolorphœite are really pseudomorphs after olivine. Some of the olivine pseudomorphs showed spherulitic and sub-spherulitic structure, due to the fibres having been arranged with a more or less radial symmetry within the crystal.

There is no doubt that the tuff is in an advanced state of alteration, the product of alteration being partly serpentine and partly delessite or chlorophœite. When some of the sections of the cores were smoothed and polished and then examined in reflected light under the microscope they looked very much like serpentine. On the other hand it must be stated that the Majgawan tuff is very friable and crumbles as soon as it comes in contact with water whereas serpentine is neither friable nor does it crumble when immersed in water. When polished the Majgawan tuff is soft and greasy to the touch same as serpentine. The fact that the ground-mass does not allow light to pass through even in thin sections may be due to the fact that it is in a very finely divided state, more like serpentinous clay than serpentine. The agglomeratic character of the rock is revealed very plainly under the microscope. (See Fig. 38, Plate XXVI).

Hard siliceous Bands.

The origin of the hard quartzose bands which occur in thin layers at intervals in the greenish tuff is really hard to find from a study of the cores and their sections only. The siliceous and calcareous nature of these bands is most probably due to infiltered silica and calcite. A study of thin sections of some of these hard bands reveals the following characteristics :—

(*a*) Occurrence of silica in the form of irregular quartz grains some closely packed together, others showing a radiate structure ; some coarse, others exceedingly fine.

(*b*) Crystals of calcite some clear, others full of impurities.

(*c*) Magnetite in the form of dust, grains and large and small patches of an irregular outline.

(*d*) Slender laths and needles of dark, dark brown and greenish colours, and acicular inclusions of sillimanite.

(*e*) Greenish and yellowish-green indefinable material in round and oval patches with a fringe of magnetite grains symmetrically disposed on its circumference. (Fig. 34) These greenish patches are the result of alteration of some original ferro-magnesian mineral in the rock.

(*f*) Large brownish patches of an indefinable substance, which may have been formed by the peroxidation of original magnetite.

(*g*) Quite a lot of leucoxene.

In some of the sections of the hard bands calcite was found in abundance, in others quartz. The calcite is invaded by magnetite dust and large dark patches probably of some form of iron oxide. Besides these, there are smaller oval and circular patches of a greenish substance which probably represents the complete decomposition of some original ferro-magnesian mineral. Between crossed incols these greenish patches do not disclose any peculiarity. They only assume a very fine grained texture while the colour becomes a more subdued green. Small pyrite crystals with perfect cubical outlines were seen in a few cores of the hard bands.. Another characteristic hard band has a distinctly brecciated structure very much like that of a trappoid or porcellanite breccia the cementing medium being opaline silica, the fragments being of the nature of metamorphosed shale or ash, (Figs. 31 & 33). Some of the cores, particularly those from a lower depth presented a resinous appearance on a freshly fractured face; a silky sheen was seen on others. Besides calcite, quartz, magnetite and pyrite, zeolite crystals were found in some of the cores. It is very likely that many more minerals

PLATE IX.

Photo by K. P. Sinor.

FIG. 14.

Natives searching for diamond.

The crushed and washed conglomerate is spread out on ground specially cleared and smoothed beforehand and is then turned over and over by the palm of the hand for searching the gem.

would be found when the tuffaceous deposit is actually worked. It is also likely that some dyke rock would be met with. The majgawan agglomeratic tuff resembles in certain respects the "blue ground" of the South African diamond mines. Fig. 25/4 of Percy Wagner's "Diamond Fields of South Africa" shows a photomicrograph of an agglomeratic Kimberlite tuff from the "West-end" of the De Beer's Pipe which very much resembles the photomicrographs of the Majgawan tuff. Of course in the South African diamond mines the variety of minerals found in both the blue-ground as also the kimberlite dykes is very large whereas the number of minerals found so far in the Majgawan greenish tuff is rather limited.

Majgawan deposit a true volcanic pipe.

It appears to me that the Majgawan deposit is a true volcanic pipe. The country rock is mostly Lower Kaimur sandstone and partly Upper Kaimur sandstone. If it were not for the old workings the deposit would have escaped notice altogether as there are no special distinguishing features which would have singled it out from the adjoining rocks, a large part of the deposit lying under a variable cover of alluvium. The old miners had probably put down a few shallow pits with a view to wash the material obtained from them. They must have been surprized when they found, instead of the ordinary beds met with in other diamond mines, this peculiar agglomeratic tuff. It is also likely that they obtained some diamonds from the material excavated by them which induced them to go deeper and deeper till at the time of Capt. Franklin's visit they were working at a depth of nearly 100 feet from the surface.

Capt. Franklin had surmised that this deposit was formed in the deserted gorge of a stream. There are instances in other parts of the world where volcanic deposits have filled old river gorges. There is however one difficulty in regarding the Majgawan deposit to have been formed in the deserted gorge of a stream and that is the even grain of the material forming the deposit from the surface to a total depth of 240 feet at least, as proved by the borings. If the deposit had been formed in the deserted gorge of a stream there would have been successive depositions which would have left some marks on it such as lamination and stratification. Again, due to the sorting action of water the larger fragments and heavier material would be found underneath the finer sediments. In the case which we are dealing however both the yellowish tuff and greenish tuff are uniform as regards the size of the component grains and fragments. To my mind the deposit represents the accumulation of volcanic material ejected from a vent and that the site where the deposit occurs is that of an extinct volcano whose neck and upper part had subsequently been denuded away.

That the Vindhyans have undergone the intrusion of igneous matter may be stated as a fact from Mallet's observation. He says " Two or three trap dykes are observable in the bed of the Nerbudda and a very large one occurs near the centre of the area, the course of which is marked by an elevated ridge. No doubt a closer examination would reveal many more " (Vol. VII, Part I, Memoirs of the Geological Survey of India, P. 78). The above intrusions alluded to by Mallet were of the upper cretaceous period. It is difficult to decide about the age of the Majgawan outburst in the present state of our knowledge. When these mines are opened it is probable that dykes of an igneous rock may be found. The relationship of such dykes to the country rock will decide the question regarding the probable origin and age of this deposit. Until further details regarding the formations are known it is idle to conjecture about them.

In this connection it is interesting to observe that Dr. A. L. du Toit, the well-known geologist of De Beers Consolidated Mines Ltd., Kimberley, is of the opinion that the tuff is of late cretaceous age. Samples of the Majgawan tuff had been sent to the De Beers Consolidated Mines Ltd., in May 1929. The General Manager of this firm very kindly got the samples examined microscopically and also had them analysed chemically. A copy of Dr. A. L. du Toit's report as also the chemical analyses of two samples of the Majgawan tuff are given in the Appendix. One thing which stands out pre-eminently from his report is the fact that the Majgawan tuff has a very close resemblance to certain types of "blue ground." He says:— "The freshest samples of the rock disclose a bluish-grey tuff with a close superficial resemblance to certain types of 'blue-ground;' indeed until its foreign origin was established the cores sent were thought to have come from a particular pipe in Tanganyika that was recently being prospected by Mr. Kingsley by means of shafts and borings. . . . ."

In October 1928 I had sent a few samples of the Majgawan bore-hole cores to the Curator of the British Museum (Natural History), London. In January 1929 I received a report from Dr. W. Campbell Smith, Assistant Keeper, Mineral Department, which is also given in the Appendix as it reveals many interesting features regarding the petrology of the tuff.

Notes regarding the future workings of the Majgawan diamond mines :—

The Majgawan diamond mines, as stated before, differ essentially from the other diamond mines of Panna in that the diamond ore found in the Majgawan mines is quite different from the diamond-bearing conglomerate and the associated diamond-bearing gravels found in the mines of Panna, Itwa, Bijepur, Barghari and other places in Panna territory.

The most hopeful feature about the Majgawan mines is that the formations were found to be diamond-bearing right up to 100 feet in Franklin's time according to whose statement the diamonds became more plentiful as a shaft descended. The boring above referred to has proved that up to a depth of 242 feet from the surface the rock is exactly similar to the one occurring at a depth of about 100 feet. It is fair therefore to presume that the lower part of the formation is also diamond-bearing. Of course at present we know nothing about the grade of the tuffaceous rock but its thickness is so great and the rocks so easy to work that these mines when opened are sure to prove the best diamond mines in the whole of Panna State.

Area of Majgawan Pipe.

I should make it quite plain that the superficial extent of this formation is not very large. There is however the advantage of the formation persisting in depth. It is quite possible that the formation is diamond bearing up to, at least, 1,000 feet. In fact, in South Africa the blue ground of the Kimberley mine has been known to be diamond producing even at depths of 4,000 feet. The Majgawan deposit is roughly oval in outline, the long diameter being 1,500 feet approximately and the short diameter,

PLATE X.

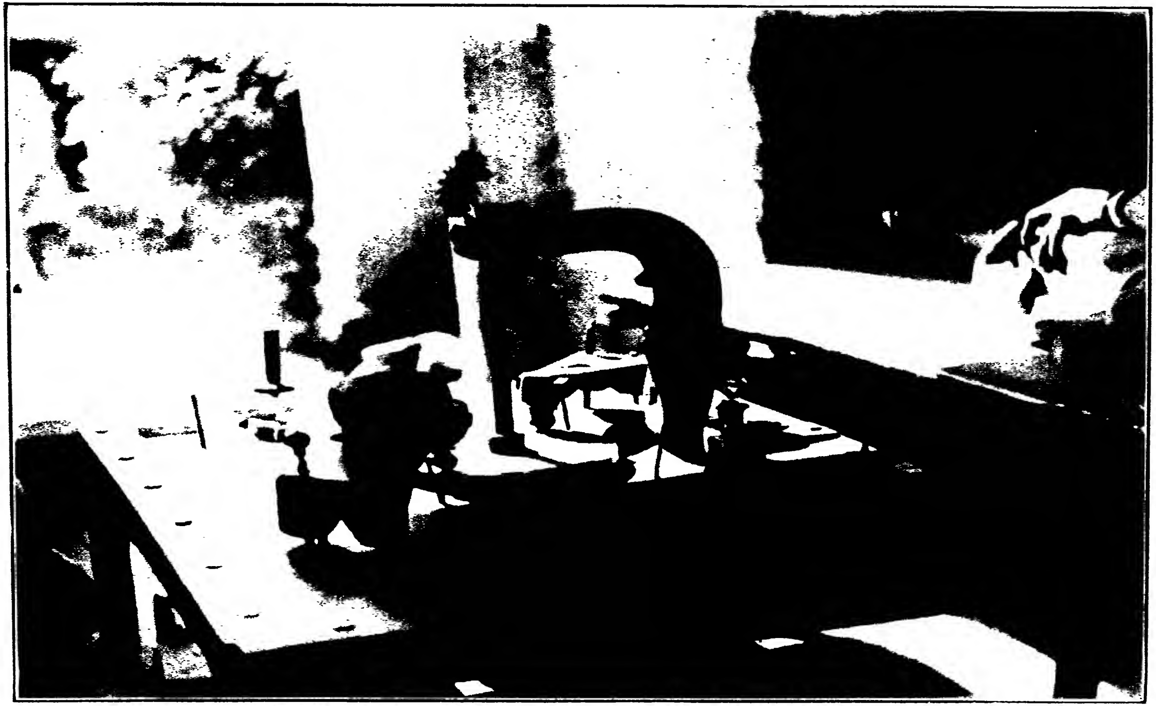

Photo by K. P. Sinor.

FIG. 15.
Diamond Polishing Machine.
Two dops containing diamonds are placed at the proper angles for the cutting of facets on the polishing wheel. The dops are held by means of iron clamps and kept in position by heavy weights.

about 1,000 feet. (Fig. 42, Plate 28). In this respect it compares favourably with some important diamond-bearing pipes in South Africa. Up to the present, only this pipe has been located but it is possible that in the area further to the south-west of Majgawan near Kusmani and Barát and at Káchá, Umarjálo, and Bamuká to the north of Majgawan other pipes would be found by systematic trenching and pitting.

No records available to show the past history of the workings.

It is unfortunate that there are no records left to show for how many years the Majgawan mines were worked formerly and what was the annual production of diamonds from these mines. I have had access to nearly all the available old records regarding the diamond workings but no mention was found in any of them regarding the Majgawan mines. The only information available is that one Mr. Manley, State Engineer, in Maharaja Rudr Pratap Singh's time had sunk a large pit in Majgawan but as the soft formations kept caving in, he had to line the shaft with segments of thick sheet iron. How far his attempts succeeded is not definitely known.

Future working of the Majgawan Mines.

In my opinion local men with a small capital should on no account be allowed to work these mines. There is every reason to believe that these mines will prove to be an important asset to the State. As the area of the pipe is limited in superficial extent it is absolutely necessary that the future mining operations should be conducted on a sound and systematic basis so that advantage may be taken of the diamond ore occurring in depth. If local men were allowed to work in this area they would spoil the whole field, much in the same way as Itwa, Bijepur and Shahidan mines have been, by hap-hazard modes of working. The working of the Majgawan area in a systematic and thorough-going way will require a large capital and unless and until a large firm of repute with the necessary financial backing is prepared to work in this area it is better to allow the mines to remain dormant. Before the actual mining operations are undertaken some further prospecting will have to be done. More bore-holes will have to be put down to prove the total thickness of the tuff in different parts and its superficial area. To test the grade of the diamond-bearing tuff a small prospecting shaft will have to be sunk and carried down as far as possible. Such a shaft will have to be properly lined with brick or stone, preferably the latter, to allow it to stand properly and also to prevent the influx of the water. For testing the diamond-bearing ground, the diamond washing pan recently ordered will serve the purpose admirably. A diamond-washing pan works best when the ore contains some clayey or shaly material. The Majgawan "green ground" when lixiviated with water would give the right consistency to enable the pan to work at its best. Jigs will not be found to be so suitable as the diamond-washing pans. The former are more suited for the concentration of clean ore free from much admixture with clay or shale. In my notes on concentrating operations further details will be found regarding the methods generally adopted in washing and treating diamondiferous ores.

Brief review of the technical reports on the Majgawan tuff.

Before closing this Chapter on the Majgawan diamond mines I may state that besides sending a few selected specimens of typical bore-hole cores to the Curator of the Natural History Museum, Mineral Department, South-Kensington, London, in October 1928, and bulk specimens of the same to the Manager of the DeBeers Consolidated Mines Ltd., Kimberley, South Africa, in May 1929 a parcel containing about 100 lbs. by weight of the cores was sent at about the same time to the Imperial Institute, South-Kensington, London, for concentration of diamonds, mineralogical examination and chemical analysis. All the three reports are interesting as they throw light on the Majgawan tuff from different points of view. They are given verbatim in the appendix.

My notes on the Majgawan agglomeratic tuff were written for the Panna Durbar before I had received any of these reports. My observations were mainly based on microscopic examination and not on chemical analysis. In many respects the Majgawan tuff resembles the Kimberley blue ground. For instance, the chemical composition of the Majgawan tuff is similar to that of the Kimberley blue ground. The percentage of silica is about the same in both the rocks. As regards other constituents also there is a close parity with the exception of magnesia and titanium dioxide. As regards mineral composition there are of course some noteworthy differences such as the absence of diopside, enstatite, phlogopite, melilite, graphite and bronzite in the Majgawan tuff. Both contain garnet, zircon, serpentine, chlorite, calcite, dolomite, chalcedony, pyrite, ilmenite. The groundmass of both the blue-ground and the Majgawan tuff consists of serpentinous clay. According to Dr. A. L. du Toit the Majgawan tuff has a close superficial resemblance to certain types of " blue-ground."

From an economic view point the vital thing which has to be cleared is whether the tuff, be it of the nature of limburgite or kimberlite is diamond-bearing or not.

From Capt. Franklin's and Dr. Medlicott's observations recorded in the publications of the Geological Survey of India it is quite plain that the tuff had been worked to a depth of 100 feet in Capt. Franklin's time and that when Dr. Medlicott visited the mines the miners were working the yellow clay, the result of decomposition of the green tuff, which latter occurs at a depth of about 110 feet from the ground level in the particular part where the bore-hole was put down. The result of the concentration test for diamonds carried out by the Imperial Institute, London, is negative inasmuch as no diamonds were found in the final concentrates obtained from a sample weighing 85 lbs. Though the suggestion for concentrating the tuff and testing it for diamonds was made by me it must be confessed that the results obtained from the concentration of cores weighing in all 85 lbs. cannot be said to be representative of the whole field particularly as the cores were obtained from one borehole only. If the borehole cores were of a larger diameter, if they had been obtained from three or four parts of the same field and if their weight had been anywhere near 2,000 lbs. the results would have been more reliable.

In his " Diamond Fields of South Africa " Dr. Percy A. Wagner gives an instance of the testing of borehole cores obtained from the area which is now known as the Premier Mine. He says: " Of the borehole cores one attained a depth of 1,001 feet in blue ground and another a depth of 826. Even the borehole cores in all about 1·6 loads, were tested and *mirabele dictu* yielded 2 carats of diamonds equivalent to 1·26 carats per load ". This result was obtained from cores weighing in all over a ton. The best way of proving whether the tuff is diamond bearing or not is to sink a prospecting shaft to a depth of about 200 feet and wash the stuff obtained during the

PLATE XI.

Photo by K. P. Sner.

FIG. 16.
Diamond searchers at work.
The heap seen in the background consists of crushed and washed conglomerate.

sinking process on rotary washing pans. I strongly recommend that the Panna Durbar should take this work in hand at the earliest opportunity.

The Wajra Karur Agglomeratic tuff.

It would not be out of place here to give a short description of the volcanic "neck" discovered many years ago in the Madras Presidency. About the year 1881 quite a stir was created among those interested in diamond mining in India by the discovery near Wajra Karur (Lat. 15°-2′: Long 77°-27′) in Bellary district of a volcanic pipe filled with a decomposed basic rock closely resembling the Kimberley "blue-ground" in outward appearance. The rock was found by Foote on investigation to be of the nature of an agglomeratic tuff which pierced the epidotic granite gneiss forming the country rock. A company was formed to work the deposit and one Mr. Copley, an experienced diamond digger from Kimberley very ably carried out the prospecting work by sinking deep shafts in different parts of the neck. The stuff which was mined was treated by means of washing machinery specially installed for the purpose but unfortunately no diamonds were found in it. Foote described the tuff as a decomposed greenish rock, rough and earthy looking, and very friable. Lake who examined thin sections of the rock under the petrological microscope found that the rock was not serpentinous. He found the rock to be composed of the following minerals: Augite, felspar, olivine imbedded in chlorite and a talc like substance. The rock was run over by veins and sheets of calcite. The original rock from which the tuff is derived is supposed to be a plagioclase-augite dyke-rock. It will thus be seen that the mineral composition of the Wajra Karur rock differs considerably from that of the Majgawan tuff. It is interesting to compare the analyses of the Majgawan and Wajra Karur tuffs with that of a sample of the bluish-green Kimberlite tuff of the Premier-Mine in South Africa.

CHEMICAL ANALYSES.

	Majgawan tuff.	Kimberlite tuff, Premier Mine.	Wajra Karur tuff.
Silica	37.36	38.15	44.73
Alumina	4.49	1.19	12.83
Ferric Oxide	3.48	6.55	4.42
Ferrous Oxide	5.11	3.24	....
Titanium dioxide	5.70	1.72	....
Chromic oxide	0.11	....	....
Lime	7.24	4.13	10.35
Magnesia	16.47	27.33	15.99
Potash..	0.50	0.56	....
Soda	0.62	0.25	....
Sulphur	0.36	....	....
Sulphuric anhydride ..	0.14	....	....
Phosphoric anhydride ..	1.89	2.15	....
Carbon dioxide	6.03	1.41	2.85
Manganous oxide	0.17	....	....
Moisture at 105° c.	6.06	9.69	9.07
Combined water above 105°c.	4.48	3.52	....
Carbon	0.07	....	....

Though no diamonds were found in the Wajra Karur pipe it is interesting to relate that diamonds had frequently been found in localities close to Wajra Karur. Mr. R. S. Orr, well-known diamond merchant of Madras and Mr. Mathew Abraham, well-known diamond cutter of Bellary, had assured Foote that they had repeatedly purchased good diamonds from places close to Wajra Karur. In the year

1881 a large diamond weighing $67\frac{3}{8}$ carats in its rough state was found near Wajra Karur. It was purchased by Messrs. P. Orr & Sons of Madras by whom it was cut into a very fine brilliant of the first water weighing $24\frac{5}{8}$ carats.

Chhila workings at Manour, Darera, Bandi and Maraia.

Besides the above mentioned workings, there are old Chhila workings at Manour, Bandi, Darera and Maraia, all of which lie in a belt more than three miles long and about a mile in width. There are no active workings in this area at present.

CHAPTER IX.

PHYSICAL CHARACTERS OF THE PANNA DIAMONDS.

Crystallography of the Panna Diamonds.

The Panna Diamonds occur in one or other of the following three crystal forms belonging to the cubic system :—

1. The hexakis-octahedron.
2. The tetrakis-hexahedron.
3. The hexakis-tetrahedron.

Most of the Panna diamonds which weigh over one rati belong to the hexakis-octahedron. This form is produced by the development of six additional crystal faces on each face of the simple octahedron. The total number of faces on the hexoctahedron is 48. (See Fig. 17 /1). Another crystal form in which the Panna diamonds occur is the tetrakis-hexahedron which is bounded by 24 faces, each of which is an isosceles triangle (Fig. 17/ 3). Four of these faces together occupy the position of one face of the cube (hexahedron) whence the name commonly applied to this form. Another form, one in which most of the smaller diamonds of Panna State occur, is the hexakis-tetrahedron which is also bounded by 24 faces. This is really a hemihedral form produced by the development of alternate faces of the hexakis-octahedron. No other forms such as the simple octahedron, the cube or the dodecahedron have been found amongst the Panna diamonds, though such forms are known to occur in South Africa.

It should not be supposed that only the larger diamonds have perfect crystal outlines. A diamond weighing only

PLATE XII.

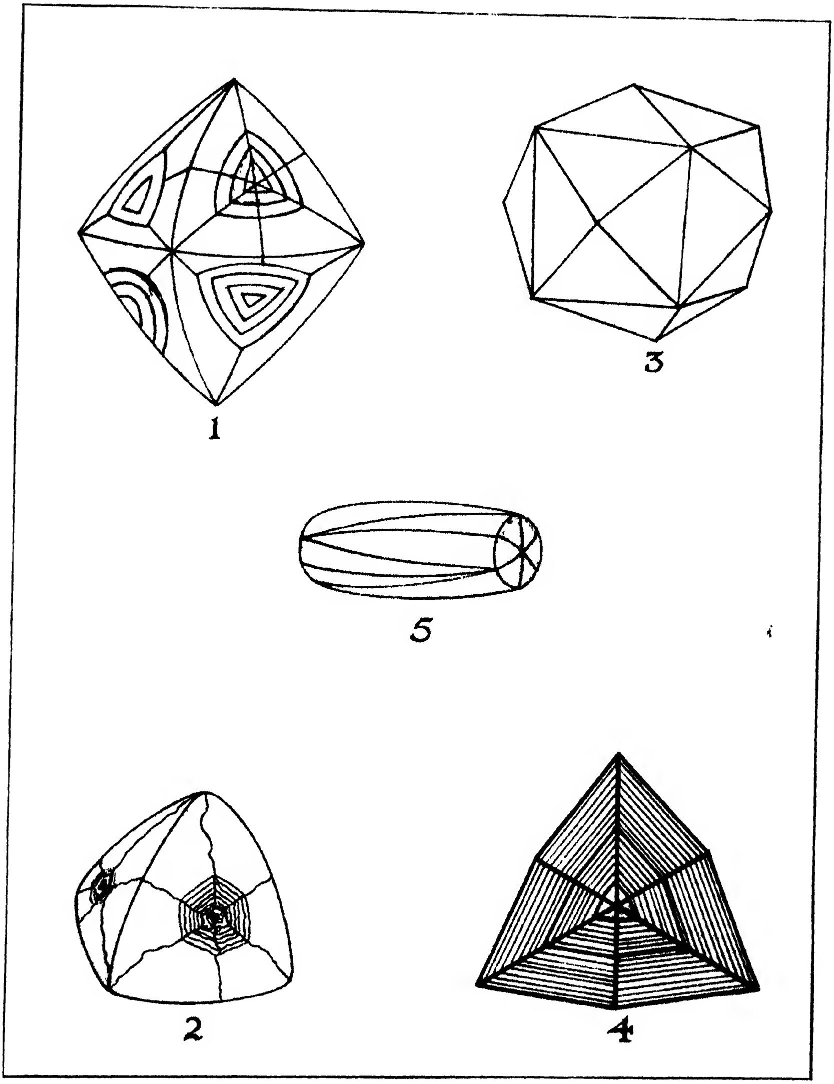

FIG. 17.

1. *The crystal-form known as the hexakisoctahedron the faces of which are occasionally covered with a tracery of striations running parallel to the curved edges.*
2. *The hexatetrahedron.* 3. *The tetrahexahedron.* 4. *Tracery commonly seen on the octahedroid faces of Panna diamonds.* 5. *Bolster shaped crystal of diamond formed by the irregular development of the different faces of the tetrahexahedron.*

All the above illustrations are diagrammatic.

about 6 biswas (*i.e.*, 6/20 of a rati) found in the Maharajpur river gravel workings on the 5th June 1928 was as perfect a tetrahexahedron as one could expect in a diamond of this size. The diamonds which occur as hexakis-tetrahedra are not so perfect in crystal outline. Although most of the hexakis-octahedra have more or less perfect outlines some of them have distorted faces due to unsymmetrical development. A notable instance of this kind was a crystal weighing 20 ratis and 2 biswas found in the Niranpur mines in May 1928. Not only was this crystal of a distorted form but some of the faces thereon showed well-marked corrugations. Incidentally, it may be stated that the shape of a crystal has nothing whatsoever to do with its water and lusture. A diamond crystal may be almost geometrically perfect and still it may be a poor diamond while a crystal which may be distorted from a crystallographic point of view may be of the first water. The irregular diamond crystal mentioned above was of very good water.

Natural shapes of Panna Diamonds.

As the different faces of a diamond crystal are not quite flat but have convex outlines many stones appear globular in habit when all the faces are more or less equally developed. The small diamond crystal belonging to the tetrakis-hexahedron class mentioned above which is in the writer's possession and which has perfect geometrical outlines appears almost like a glass bead to the naked eye. Some of the hexakis-octahedra of the Panna mines appear almost spherical owing to their strongly curved contours, while in others the octahedral outline shows clearly owing to the six-sided pyramids being somewhat shallow. In the collections examined by me I have seen more of the latter than of the former class. Besides the ordinary hexoctahedra in which all the crystallographic axes are equally developed, a few forms occur in which one of the horizontal axis is longer than the other. Distorted forms of hexoctahedra have also been seen; these forms are produced by more pronounced development of some faces and very poor development of others. Flat crystals with more or less triangular outlines and having a shallow six-faced pyramid on each face occur commonly in the Panna mines. These forms belong to the hexatetrahedron class. They have 24 faces in all, 12 on the two flat faces and the remaining 12 on the girdle. Such tabular crystals are known as flats in South Africa.

Distorted forms of the tetrahexahedron class also occur in Panna mines two of which deserve particular mention. In one which is of the shape of a barrel or a bolster the two ends have six faces each while the remaining 12 faces are spread out on the cylindrical part (See Fig. 17/5). In the other form which is tabular the flat sides have six faces each, while the remaining twelve faces are compressed on the girdle. Both the forms belong to the same crystal class but in one, a particular set of crystal faces is strongly developed whereas in the other the same set is poorly developed. I saw many such flat diamonds in the collections which I examined from time to time. In South Africa, such flattened stones are known as "flats." In some other crystals there are two prominent and well-developed faces on each flat side while the remaining 20 faces occupy the middle part.

Size of Panna Diamonds.

The Panna mines have not produced any diamonds of remarkable size. The largest diamond ever discovered was the Cullinan, found in the Premier Diamond Mine in South Africa. It weighed in its natural state 3,025¾ Carats

(1·37 lbs. avoirdupois). The original diamond, of which the Cullinan was only a cleavage fragment, must have been considerably larger. Large stones of such remarkable size cannot be expected to occur in a conglomerate formation such as the one in which the Panna diamonds occur, as the very nature of such a formation and the mode by which it was formed preclude the possibility of their occurrence. Very large stones can only occur in volcanic pipes.

In this connection it may be stated that as the Majgawan diamond bearing formation consists of an agglomeratic tuff, similar, if not identical, to the agglomeratic tuff found in the South African mines it is possible that large diamonds may be found in that area.

According to Hamilton, in his time (about the year 1813) a good many stones were found in the Panna diamond mines worth from Rs. 500 to Rs. 1,000 and he says that the Raja had one supposed to be worth Rs. 50,000. In 1904 a diamond weighing 31 ratis and 8 biswas was obtained from the Shahidan mines, then valued at Rs. 4,396. In 1928 a diamond weighing 20 ratis and 2 biswas was found in the Niranpur mines, valued when cut at Rs. 11,000, approximately.

Average weight of Panna Diamonds.

The average weight of the Panna diamonds below 6 ratis, produced during the last 10 years from the Shahidàn mines is 1·105 ratis while the average of the same class of diamonds obtained from the Itwa mines is 0·621 rati. The average weight of diamonds weighing above 6 ratis for the same period is 9·5 ratis for the Shahidan mines and 6·5 ratis for the Itwa mines.

The smallest diamond from the Panna mines which I have seen weighed about half a biswa (20 biswas are equal to 1 rati). As the diamonds are picked out by hand from the washed diamond-bearing gravel it is difficult to get smaller sized diamonds than the above. In South Africa where the diamonds are automatically sorted out from the heavy concentrates by the grease-table or the greased frue-vanner a number of very small diamonds are obtained. Such minute stones are known as sand diamonds as they appear like so many particles of sand. In Panna, for purposes of valuation a diamond weighing less than a biswa is considered equivalent to a biswa.

Cleavage fragments, Twin Diamonds.

As the Panna diamond-bearing conglomerate is broken by large hammers it is natural to expect some broken diamonds in the total yield. It is a fortunate circumstance, however, that such broken diamonds are usually few, which shows that they are not very firmly cemented in the standstone or shaly matrix. The diamond, though the hardest substance known, is brittle.

I had examined a number of Panna diamonds but amongst the whole lot I found only a few twin crystals which are called "macles" in South Africa.

Colour.

The Panna diamonds may be classed into six groups according to their colours :—

1. Water-clear.—Such diamonds appear brilliant white and occasionally blue-white when cut and polished.
2. Of a very delicate greenish colour—Such diamonds are locally known as '*bānspat*', *i.e.*, of the colour of fresh bamboo leaves. These diamonds are highly prized.

3. Of a stronger greenish colour with a tinge of yellow.
4. Greyish.
5. Yellowish.
6. Of dirty-brown and dirty-grey colours. Such crystals are usually full of flaws and inclusions and are known in the vernacular as "mattha." In South Africa such crystals are classed in the trade as 'rubbish' or 'rejections' as they are unsuitable for use in jewellery.

Coloured diamonds, known as 'fancy goods' or 'fancy stones' in the trade, do not occur in Panna mines. Only one small sapphire-blue crystal has been found so far in Panna State and that was recently (in May 1928), from the river gravel workings near Maharajpur. The greenish-coloured stones mentioned above appear almost colourless when cut and cannot therefore be classed as coloured diamond.

The following peculiarities were observed in Panna diamonds :—

Some Peculiarities of Panna Diamonds.

1. Lenticular Markings.—Some Panna diamonds exhibit under the microscope characteristic lenticular markings on the outer skin when viewed under the microscope with a one-inch objective (Fig. 41). Other diamonds shew, under the same magnification, a dented surface resembling that of hammered copper.

2. Striations.—The crystal faces of many Panna diamonds exhibit striations which usually bear a certain definite relation to the crystallographic axes. The most common structure, produced by the striations cutting the

six-sided pyramids on one or more faces of the octahedron, resembles a spider web. The tracery thus formed is shown diagramatically in Fig. 17/4.

3. Other Surface-markings.—A very interesting feature of the Panna diamonds is the presence on the faces of some of these stones of peculiar pittings or markings of hexagonal or triangular shape. These markings mostly occur as inverted triangular depressions and occasionally as elevations on one or more faces of the diamond. They are usually found on the apex of the 6-sided pyramid on any one or more of the octahedron faces and are found oftener in brownish diamonds. The small blue diamond mentioned above which was found in the Maharajpur river gravel workings showed characteristic markings which were triangular and which were found to be situated on striation lines. Figs. 40 & 41 show the characteristic triangular and pyramidal pittings.

The surface markings observed on the natural faces of diamond crystals were formerly called etch-marks or etching-figures from their similarity with the etch-figures produced on the natural faces of certain minerals by the action of solvents. It was first shown by Fersmann and Goldschmidt that they were phenomena connected with the growth of the crystals and not of their solution as was formerly supposed ; growth, at a slow rate in the case of depressions and at an accelerated rate in the case of elevations. The word " trigons " is also used for these figures for the sake of convenience.

4. Greenish Tinge.—Diamonds of a delicate greenish tinge appear perfectly white when cut and polished. It appears therefore that the colouring matter does not penetrate the entire crystal but is only restricted to the

PLATE XIII.

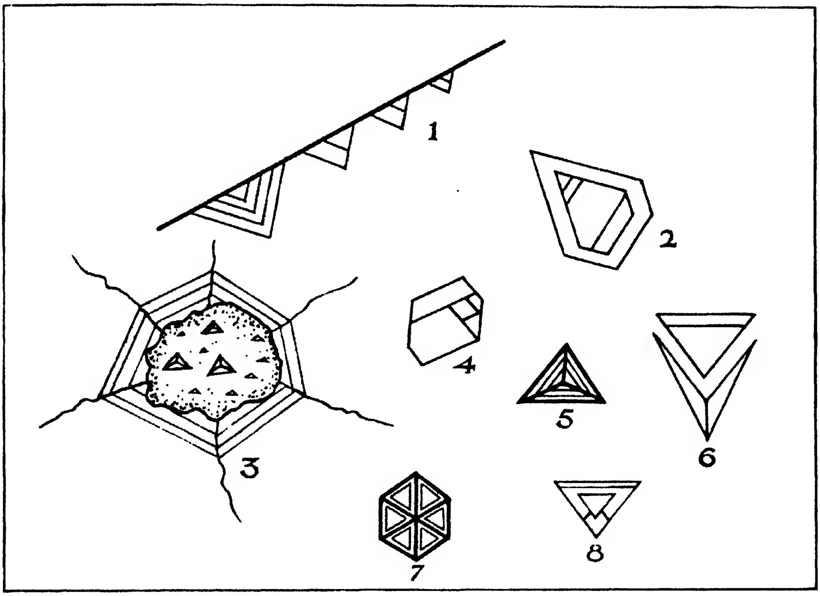

FIG. 18.
Surface markings, also called "etch-figures," seen on Panna diamonds.

FIG. 18a.
Photomicrograph of the granophyric quartz-plagioclase augite rock of the Bijawar series. Ordinary light. Magn. 30.

Photomicro by K. P. Sinor.

outer skin. Such diamonds are highly prized by the local diamond merchants.

Diamonds with a pronounced yellowish-green colour are not considered to be so good because according to the local diamond-cutters the yellow tinge persists even after such a stone is cut and polished while the green colour disappears.

5. Corrugations on some of the crystal faces.—A characteristic feature which I found in a few large stones was the presence of corrugations or flutings on some of the faces. It was most marked in the crystal weighing about 20 ratis found in the Niranpur mines to which reference has been made before.

6. Anomalous Double Refraction.—Diamonds have been known to show anomalous double refraction in consequence of internal strain. I examined many Panna diamonds under the polarising microscope and found that most of them showed polarisation colours between crossed nicols. In most cases I observed coloured bands such as are usually shown by thin sections of calcite. Such coloured bands and stripes were best shown by brownish crystals. Very clear crystals in which all the faces were symmetrically developed showed very little or no double refraction. Crystals full of flaws and inclusions and distorted crystals showed the colour bands very well.

7. The surface of the crystals.—It is a thing worth noting that the surface of the Panna diamonds is in the majority of cases highly lustrous and smooth as glass. Specimens with frosted or rough surfaces are rare.

8. Green spots and inclusions.—I saw acicular inclusions in a few Panna diamonds under the microscope. Black

inclusions of an irregular shape and having jagged outlines are more common. The most noteworthy peculiarity which I observed is the presence of minute green circular spots some of which can be seen with the naked eye. It is not only in the greenish diamonds that green spots and dots are seen. I saw them in the clear stones as also in the deep brownish stones. Most of these spots, however, are too minute to be seen with the naked eye. Crystals stained with hæmatite occur very sparingly.

CHAPTER X.

DIAMOND CUTTING AND POLISHING IN PANNA

The cutting of the diamond and its preparation for use in jewellery involves the four distinct operations of splitting, cutting, setting and polishing. The natural crystal of diamond, requires in many cases to be split in two or more parts particularly if it be of an elongated or irregular shape.

Cleaving.

The operation of splitting or cleaving, as it is otherwise known, is an onerous one requiring an intimate knowledge of the crystallography of the diamond for its successful performance. I have seen the Panna diamond cutters perform the operation with great dexterity, they having acquired the necessary skill not only by years of assiduous toil but as a part of their heritage as the profession is handed down from father to the son. Large diamonds are frequently sent to Panna to be cleaved. The rough diamond to be cleaved is so cemented in a holder that the plane of cleavage lies parallel to the length of the holder which is firmly fixed upon the cutter's working-bench. The cementing medium used by the Panna cutters is a composition made of shellac and powdered marble. When the crystal is properly fixed in the cement the cutter makes a groove or notch in it in the direction in which the stone requires to be cleaved This operation is performed by a pointed splinter of another diamond which is mounted on a wooden stick and cemented thereto by shellac. When a groove of the requisite depth is cut the cleaver inserts a steel blade in it and deals to it a smart blow thus dividing the stone in two parts of the requisite size. Sometimes the operation of cutting the groove is omitted, particularly when the stone has to be detached along a cleavage plane. In Antwerp and other diamond-cutting centres in Europe slitting machines similar to those used by petrologists for cutting thin rock sections are employed for cutting diamonds. They consist of a thin iron disc charged with diamond dust on its periphery which is rotated at a high speed, the diamond to be cut being held against it at a uniform pressure. The advantage of this machine lies in the fact that a diamond may be cut in any direction with its help and also that large diamonds could be safely cut by it. The disadvantages are that large stones may take three or four weeks to cut and secondly stones cut by this method are alleged to lose their brilliance during the operation so that even when finished they are stated to lack the lustre of stones cut by the first method. Two or three diamond cutters of Bombay have installed slitting machines but I have been told that they have not been very successfully used so far.

Bruting.

The second operation consists of roughly reducing the split pieces to the shape required, whether it be a brilliant, step-cut or rose. This operation which is called bruting is performed by rubbing a specially mounted diamond with the diamond to be shaped. The cutting diamond is mounted on a cylindrical piece of iron by means of shellac cement at one end. In the middle of this thick rod there is a recess specially grooved out so that it could be made to rest on an adjustable vertical metal shaft which is firmly held in the work-bench. The diamond to be shaped is fixed in another holder with the help of cement and placed directly below the cutting diamond. The latter is then moved from one side to another repeatedly till the first diamond assumes the required shape. Facet after facet is thus roughly marked out on the diamond to be shaped.

Setting and polishing.

The roughly shaped diamond is then handed over to the setter who sets the stone in a copper cup with the help of an alloy consisting of a mixture of tin and lead. The shape of the cup with its stem and of the alloy filling it resembles that of an acorn at the apex of which the diamond is set in the required position. The cup with the stem is then handed over to the polisher who clamps it in a special holder and so places it on the polishing wheel that the copper cup resembling the acorn rests on the wheel with the diamond touching it. Lead weights are then put on the holder to give it the necessary pressure and the wheel is then allowed to rotate at a speed of from 2000 to 2500 revolutions per minute. When one of the facets is polished the cup with its stem is taken out of the holder and again handed over to the setter who has at his command an earthenware vessel filled with burning charcoal. The cup is heated in the charcoal till the solder becomes soft when the diamond is adjusted in a different position for a new facet and so on till all the faces are polished. During the operation of polishing, the point of the diamond is kept constantly wet with diamond dust mixed with olive oil. The holder is provided with a device by means of which the diamond is tilted at the required angle by means of two threaded brass rods fitted with wing-nuts. By lowering the one and raising the other the diamond may be set at a different angle. (See Fig. 15).

The different forms in which the diamond is cut by the Panna cutters are the brilliant, the rose, step-cut and briolette. The accuracy with which they can produce facets even on very small stones is really surprising. To bring out the beauty of a stone it is necessary to cut and polish it according to certain fixed rules so that a ray of light entering the stone may emerge from it with the maximum of refraction. The chief point is to achieve the maximum of brilliance with a minimum loss of weight in cutting.

Diamond necklace of uncut stones.

While it is true that the maximum beauty of a good diamond could only be revealed by cutting and polishing it according to certain known methods, some diamonds occurring in their natural state are found to have a peculiar beauty of their own. In Panna State well formed crystals showing a good lustre are frequently found, a few of them with a delicate greenish tinge which in the estimation of some have a beauty surpassing that of the cut gems. One of the former rulers of Panna who was apparently of an aesthetic turn of mind had a necklace made of 52 graded Panna diamonds in their natural state, Fig. 19. It is an heirloom and is worn by the rulers on occasions of State. This necklace is most probably unique of its kind. A clasp set with four rough diamonds as jewels known as the clasp of Charlemagne has been described by Streeter but not a necklace made of so many graded diamonds.

Ratio of the Panna rati to the Carat.

It is unfortunate that the rati weight generally used for weighing diamonds by Indian merchants has not been standardized. This inevitably leads to a certain amount of confusion. Thus, the Panna rati is different from the Bombay rati which again has a different value from the Madras rati and so on. The English carat which was in use

PLATE XIV.

Photo by State Photographer, Panna.

FIG. 19.

Necklace made of 52 uncut and unpolished Panna diamonds occurring in their natural state. The largest stone is 25 ratis in weight, the smallest stone being 1½ ratis. The total weight of all the diamonds in the necklace is more than 325 ratis.

for many years and which had been defined by the Board of Trade was equivalent to 3·1683 grains troy or 205·304 milligrammes. It was the unit of weight for precious stones in the United Kingdom and in British South Africa for a number of years till it was superseded by the Metric Carat of 200 milligrammes or 3·08647 grains troy. The use of the metric carat was made compulsory by law in France many years ago. It may be stated that 40 old English carat-weights are equal approximately to 41 metric or international carat weights. The old English carat-weight had one serious drawback which was that if a specimen did not weigh an exact number of carats its weight had to be expressed by the aid of the following somewhat clumsy fractions :—$\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$.

The origin of the carat can be traced to the seeds of the locust tree, *ceratonia siliqua*, which are remarkably constant in weight and average about 3.04 grains troy or 197 milligrammes. The Panna weight of one rati weighs exactly 197 milligrammes which shows that the Panna rati-weight was originally adopted from that of the seed of the locust tree. The Panna rati is therefore equal to 0·985 metric carat. The Bombay rati-weight is equivalent to 188 milligrammes or 0.94 carat.

The smallest weight for weighing diamonds as used in Panna is the *biswa* or besi which is $\frac{1}{20}$th of a rati. The Panna weights are made of jasper, quartz or agate which have been specially turned and polished on a lapidary's machine. The idea of making the different weights of such hard material is to prevent their being tampered with. Moreover metallic weights are liable to be gradually worn due to constant handling. To overcome both these objections the Panna diamond weights have been specially made of agate, chalcedony and other hard minerals. Sets weighing from $\frac{1}{20}$th of a *rati* to 24 *ratis* are in common use. I recommend that these weights be periodically checked with the help of a set of standard weights specially made of a hard metal by a reputed firm of manufacturers of scales and weights like Oertling's, the *rati* being made equivalent to 197 milligrammes or 3.04 grains troy as it is at present.

CHAPTER XI.

THICKNESS AND GRADE OF THE DIAMOND-BEARING CONGLOMERATE.

The thickness of the conglomerate varies from place to place. It is also an observed fact that in one and the same field the conglomerate is thicker in one part than in another. This is what one would naturally expect considering the uneven nature of the floor on which the conglomerate was deposited during its formation. The surface of the Upper Kaimur sandstone on which the conglomerate rests is not perfectly level but undulating, and corresponding to these differences in the level of the floor there are differences in the thickness of the conglomerate. It is also likely that in some parts there is no conglomerate. These factors should be taken into consideration when estimating the total yield of diamonds from any particular field.

The thickness of the conglomerate bed varies again according to the locality of the field. Thus, in the Shahidan area the thickness of the conglomerate bed is about a foot, taking into consideration the bed of kakru overlying the muddha and the shaly bed in between the two, both of which are treated for diamonds and which are called '*ranjka*' and '*gilta*' by the miners. Even here I have noticed considerable variations in the thickness of the conglomerate from 3 inches up to about 1½ foot. In the Barghari mines I have seen a conglomerate bed 5 feet in thickness and in another part of the same field a bed only about 2 feet in thickness. These are the only two fields in which I have been able to ascertain personally the thickness of the diamond-bearing bed. The thickness of the conglomerate which was previously mined at Birjpur has been recorded to be 2 feet. These mines ceased working years since and though I visited the site of the old mines I could not find anywhere an outcrop from which the thickness could be verified nor could I see any exposures of the same in any old mines.

Another matter which requires careful investigation in finding out the probable yield of diamonds from any particular field is the grade of the ore. The best way to find out the grade of the ore is to find out how many diamonds had been recovered from a particular mine and what were the cubical contents of the conglomerate mined. When these two things are definitely known the grade could easily be arrived at. The above method would however give correct results only for that part of the field in which the mine happens to be situated and the estimate arrived at would not be true for the whole of that area. A properly representative estimate of the grade of the ore could only be arrived at after taking into consideration the total yield of diamonds from any particular field for say 10 or 12 years and the total quantity of the conglomerate mined during that period. Although the annual yield of the Panna diamond mines has been carefully recorded for many years, the quantity of conglomerate mined has not been recorded. I had an opportunity of first seeing the Panna diamond mines in January 1920 when I saw the mines which had been put down in the previous season as also the new pits which they had commenced excavating about 6 weeks before my arrival. As a number of pits had been put down in 1919 I have thought it best to calculate the grade from the output for that year, particularly as I had seen the workings put down in that season.

Details regarding the yield of diamonds, the size of each individual diamond, the number of mines worked, the income from the sale of diamonds, &c., are very carefully and systematically recorded in a register specially kept for that purpose. I find from this register that from January 1919 to December 1919, 854 diamonds weighing 1,016 ratis and 16 biswas were obtained from 81 workings put down in the Shahidan area. There were 30 workings of a diameter varying from 20 to 30 feet while the remaining were shallow detrital workings and *chhila* workings. I reckon the total quantity of conglomerate mined in that year to be about 28,000 cubic feet. I have arrived at this figure after careful consideration of all the facts. It should be remembered that in some mines which may have happened to be on the site of old workings (*purao*) the quantity of conglomerate obtained must have been half the calculated amount for those mines. The quantity of conglomerate obtained from the surface workings is usually very small. The number of diamonds weighing less than 6 ratis obtained during that year from the Shahidan mines was 845 weighing in all 920 ratis and 8 biswas. The number of diamonds above 6 ratis obtained during the same year was 9, of a total weight of 96 ratis and 8 biswas. The total number of diamonds produced in that year was 854 weighing in all 1,016 ratis and 16 biswas. As these diamonds were obtained from about 28,000 cubic feet of the conglomerate, its grade works out at 0.036 ratis per cubic foot. The grade thus arrived at is calculated on the yield declared to the State by the mine owners. It is natural to suppose that a certain number of diamonds are not declared by the miners and mine owners; if these were taken into consideration the grade would naturally be higher.

The following table shows the monthly yield of diamonds under 6 ratis in weight in 1919 from the Shahidan mines, the weight of the diamonds and the price realised thereon :—

1919 Month.	No. of diamonds.	Weight of diamonds.		Prices realised.			Royalty paid to the State.		
		Rati.	Besi.	Rs.	a.	p.	Rs.	a.	p.
January ..	2	2	11	268	14	6	62	3	9
February ..	16	21	0	3,221	1	3	765	8	3
March ..	26	41	9	10,065	12	0	2,617	6	6
April ..	40	49	8	6,628	8	3	1,548	15	6
May ..	55	65	13	12,308	12	0	2,845	12	6
June ..	95	117	12	15,698	7	9	4,292	3	0
July ..	93	117	15	20,832	11	6	5,732	11	3
August ..	174	164	15	23,389	15	9	6,356	4	9
September ..	162	155	11	22,058	7	9	6,014	9	3
October ..	71	66	6	10,319	13	3	2,781	9	6
November ..	70	73	6	14,900	9	3	4,065	7	3
December ..	41	45	2	4,936	4	9	1,334	6	0
Total for 12 months.	845	920	8	1,40,629	6	0	38,417	1	6

The following table gives the monthly yield of large diamonds weighing above 6 ratis found from the Shahidan mines in 1919, their weight, the prices realised and the bonus paid to finders of the diamonds:—

1919 Month.	No. of diamonds above six rati.	Weight of diamonds.		Prices realised.			Bonus paid to the finders.		
		Rati.	Besi.	Rs.	a.	p.	Rs.	a.	p.
January ..	..	..		..			..		
February ..	..	..		..			..		
March ..	1	6	5	1,918	12	0	239	0	0
April ..	1	10	12	3,922	0	0	405	7	3
May ..	..	..		..			..		
June ..	1	9	19	2,099	7	3	211	7	0
	1	10	13	3,269	8	9	362	1	7
	1	17	10	7,875	0	0	1,338	12	0
	1	10	2	505	0	0	68	10	11
July ..	..	..		..			0	0	7
August ..	1	6	14	475	11	3	62	10	1
September ..	1	7	18	2,093	8	0	167	14	0
	1	16	15	10,050	0	0	1,708	8	4
October ..	..	..		..			..		
November ..	..	..		..			..		
December ..	..	..		..			..		
Total for 12 months ..	9	96	8	32,208	15	3	4,564	8	1

I have also calculated the grade of the conglomerate in the Shahidan field from the results obtained from one particular pit which was worked in 1926. I specially selected this mine for calculating the grade because it was large and because it was more systematically worked than many others, the owner, one Heeralal Dhami, having previous experience of mining in the Shahidan field. I find from the diamond mines register that the total number of diamonds obtained from his pit was 41, weighing in all 47 ratis and 14 biswas. The total quantity of the conglomerate produced from his mine was about 1,000 cubic feet. The grade of the conglomerate thus works out at 0·0479 rati, *i.e.*, ·04718 carat. I believe that this is the more correct result. In the case of the grade calculated from the results of the workings in 1919, while the figure regarding the output of diamonds is quite correct that regarding the total quantity of conglomerate mined errs probably on the more generous side; that is why the two results do not agree.

Size and Value of Panna Diamonds. Royalty charged on Panna Diamonds.—The average size of the diamonds under 6 ratis found in the Shahidan diamond field (which includes Srinagar, Ogra, Karra, Chunha and Shahidan mines) as calculated from the returns of the 11 years from July 1917 to June 1928 is 1.09 rati. The average size of the diamonds under 6 ratis found from Itwa mines during the same period is 0.62 rati. I have also calculated the average size of all diamonds under 1 rati and above 1 rati obtained from the Shahidan and Itwa mines. The results are as follows:—

	Shahidan field. Rati.	Itwa field. Rati.
Average size of diamonds under 1 rati ..	0.523	0.358
„ „ „ above 1 rati ..	1.87	1.67
„ „ „ above 6 ratis ..	9.5	6.5
„ „ „ small & large under 6 ratis ..	1.09	0.62

The proportion of small diamonds less than a rati is 58·3 per cent. in the Shahidan field and 80 per cent. in the Itwa field. The proportion of diamonds above one rati and below 6 ratis is 41·7 per cent. in the Shahidan field and 20 per cent. in the Itwa field. The averages arrived at have been deduced from the figures regarding the production of diamonds from the Shahidan field during the 10 years from July 1917 to June 1927.

The Panna diamonds are sold by public auction in Panna every four or five months when there is a fair collection. The prices realized vary from time to time and depends on whether there is a good demand for the stones or not at the time of the sales. The stones are mostly purchased by local merchants but some Bombay dealers occasionally come to Panna to buy the diamonds. The average prices of the diamonds, realized during the 10 years from July 1917 to June 1927, were as follows :—

Value of Panna Diamonds.

Average price of diamonds obtained from the Shahidan field from July 1917 to June 1927 :—

	Per rati. Rs.	a.	p.
For stones under 1 rati	58	10	0
For stones above 1 rati and under 6 ratis	171	12	0
For all stones, large and small, under 6 ratis	139	7	0

Itwa mines—Average of 10 years from July 1917 to June 1927 :—

	Per rati. Rs.	a.	p.
For diamonds under 1 rati	43	2	0
For diamonds larger than one rati but under 6 ratis ..	119	6	0
For small and large diamonds under 6 ratis	84	2	0

Average value of Shahidan diamonds obtained from July 1919 to June 1920 :—

	Per rati. Rs.	a.	p.
For stones less than a rati	58	4	0
For stones above one rati but under 6 ratis	196	0	0
For all stones, small and large, below 6 ratis	154	12	0

Average value of Itwa diamonds obtained from July 1919 to June 1920 :—

	Per rati. Rs.	a.	p.
For small diamonds weighing less than a rati	46	7	0
For diamonds above one rati but under 6 ratis	133	2	0
For large and small diamonds below 6 ratis..	68	1	0

All diamonds above 10 ratis are, at present, considered to be the property of the State. Before the year 1925 all diamonds above 6 ratis became State property.

Rates of the Royalty charged by the Panna State.

The following are the rates at which the royalty is at present charged by the Panna State on diamonds mined or found within Panna territory.

Diamonds obtained from Deep Mines :—

Size of diamonds.				Royalty.
From 1 to 5 ratis	..	..	..	20 per cent.
From 5 to 10 ratis	..	..	..	25 " "

Diamonds above 10 ratis become State property, the Mine-owner receiving 33 per cent. of the estimated value as prize-money. Diamonds above 10 ratis are not put up for auction. For the calculation of the prize-money the diamonds are usually evaluated by two valuators (*jaria*) on behalf of the State and three persons from among the local merchants (Mahajans) on behalf of the mine-owners and the finders.

Shallow (*chhila*) Workings.

Size of Diamonds.			Royalty. Rs.	As.	
From 1 besi up to 3 ratis	..	..	23	1¾	per 100 rupees value.
From 3 ratis 1 besi up to 4 ratis		..	25	1¼	Do.
From 4 ratis to 10 ratis	..	..	33	8	Do.

For diamonds above 10 ratis the mine-owner is given 17 per cent. of the estimated value as a prize.

Stray diamonds.

The above scale for *chhila* workings is also in use for diamonds not actually mined but found accidentally on the ground or soil anywhere in Panna territory. Such stray diamonds picked up from the ground are locally known as "daré" डरे diamonds.

Extent of the diamond-bearing conglomerate.

The older of the two diamond-bearing conglomerates is known to occur in Panna territory within a belt 30 miles long and about 3 miles in width which runs in a north-east to south-west direction. The most westerly place where the gravel derived from the older conglomerate is known to occur is near Majgama, the easternmost locality being Gehra on the Baghen river. The newer conglomerate workings lie in an area about 20 miles long and about 4 miles wide in the eastern part of Panna territory on the Upper Rewa plateau. The richest diamond mines occur in the older of the two conglomerates. The area within which the old conglomerate is distributed is about 90 square miles. What proportion of this area is sufficiently rich in diamonds to give possibilities of commercial operations is a matter which requires still further investigation. As I have stated before, the older conglomerate bed dips towards the south. The further the workings extend in the direction of the Rewa scarp the greater will be the depth at which the conglomerate would be met with. There is another fact which should also be borne in mind, which is that if a shaft be sunk further towards the south from the present workings more and more bands of hard sandstones would be met with as is proved by the bore-holes put down at Janakpur, Kalianpur and Laxmipur. I have stated before, that the conglomerate bed is thick in one part and thin in another. In some parts it seems to die out altogether. It shows that some of the area contains rich pay-chutes well worth working while others are more or less barren. The thickening and thinning of the ore-bed is clearly seen at Barghari where the conglomerate bed is 5 feet thick in one part and in another part from 2 to 2½ feet. At Jaruapur no conglomerate was met with in the bore-hole at the usual horizon between the Upper Kaimur sandstone and the Panna shales.

Probable yield of diamonds from the conglomerate.

Even though a lot of diamondiferous area has been worked out in the past near Shahidan, Bijepur, Barghari and Birjpur there is still an extensive area of virgin diamond-bearing ground in which further exploratory work would prove richer zones. Out of a total diamondiferous area of about 90 square miles it is quite reasonable to suppose that pay-chutes well worth working occur within an area of at least 5 square miles. I have shown before that the grade of the conglomerate as calculated from the results of all the mines put down in 1919 works out at 0.036 rati per cubic foot of conglomerate ; the grade calculated from the results shown by one particular pit put down in 1926 works out at 0.048 rati per cubic foot. Even supposing the grade to be still less than either of the above, say 0.03 rati per cubic foot, the total probable yield from the 5 square miles would be 4,181,760 ratis or approximately 4 million ratis. No one can possibly say that the above estimate is an exaggeration. In the area round about Panna, Janakpur and Kalianpur, one can surely depend on two and a half square miles of rich diamondiferous ground which would pay well to work and near Bijepur, Itwa and Barghari one may reckon on an equally rich area of the same extent leaving all the other areas in Panna territory out of consideration. There is therefore plenty of scope for a fairly large business.

Neither the probable yield from the detrital and alluvial workings in the old conglomerate nor the probable yield from the newer conglomerate have been taken into consideration in the above estimate. One particular area in the newer conglomerate, *viz.*, that in the river gorge near Udesna (Maharajpur) is reported to be very rich in diamonds. The Majgawan field has also not been taken into consideration in the estimate. As has been said in a description of these mines the diamond-bearing ground in Majgawan field is not the usual conglomerate but a basic volcanic tuff which has been proved to a depth of 242 feet from the surface and which probably extends considerably further in depth. The output from these mines is therefore bound to be considerable. Taking therefore the area covered by the newer conglomerate as also the alluvial and detrital diamond bearing ores in the old conglomerate one may safely reckon on a total yield of 8 million ratis if not more.

CHAPTER XII.

SUGGESTIONS REGARDING AN IMPROVED METHOD OF MINING THE CONGLOMERATE.

I have already drawn attention in previous pages to the disadvantages resulting from unsystematic methods of working out the ore in the Shahidan and other areas. So long as the mines are worked by different groups of owners or by different individuals in the same area the same state of affairs will continue. Unless the mining operations are conducted either departmentally or by one large concern it is difficult to see how a proper scheme of working could be evolved. Most of the mine-owners are men of small means and naturally their only concern is to get as much quick profit as possible without any regard to the fact that by their unsystematic method of working the mines a large part of the conglomerate is annually lost to the State. The suggestions which I have to make would only apply to the working of the mines either departmentally or by a large mining company.

The present system of working is not only wasteful from the point of view of the loss of conglomerate every year as before mentioned but it also represents an enormous amount of waste of energy. Suppose that a pit about 35 feet square is put down in the Shahidan area. The depth of the pit would have to be somewhere between 50 feet and 70 feet depending on its exact situation. Supposing that a pit 50 feet deep has to be sunk, it would mean that in all $35 \times 35 \times 50 = 61,250$ cubic feet of material would have to be removed from the pit alone, just for the sake of $35 \times 35 \times 1 = 1{,}225$ cubic feet of conglomerate, considering the thickness of the conglomerate bed to be 1 foot. Roughly for every 50 cubic feet of material removed 1 cubic foot of the diamond-bearing ore would be obtained. I therefore propose that some system of underground mining be introduced to prevent this enormous waste of energy.

If the formations in Shahidan had consisted only of alluvium and shales I would have recommended the method employed by the Chinese in the tin mines of Malaya where they put down shafts of very small diameter say about 4 feet which usually stand well and do not need any timbering. When the shaft has reached the desired depth the Chinese work out the flat layer of " wash " by making small drives in directions which permit drainage to the shafts. Such drives are timbered if found necessary by two posts and slab caps or round posts and slabs between the sets of timber at intervals depending on the nature of the ground. The layer of wash is stoped out and conveyed to the shaft in baskets or when the distances are long, in barrows and the same is raised in buckets by windlasses. When the distance of the workings from the shaft has increased to such an extent that the haulage cost becomes considerable another shaft is sunk and drives from the new shafts are again made in different directions till all the ore from the adjoining areas is worked out. In fact when the workings have advanced considerably there would be a set of shafts on the dip slope and another set of shafts in a direction at right angles to that of the dip. If the distance between the shafts is more than 100 feet apart, intermediate drives parallel to the lines of shafts are made to provide additional working faces. From the galleries at right angles to the dip, drives up to the slope are made connecting with a second line of shafts. When the mine is properly opened up two or more lines of shaft would always be open, each new line being developed while the preceding one is being stoped from. The ground is worked from each new line of shafts in a longwall system to the rise and raised at the nearest shaft.

The system which I propose is a modification of the above to suit the special conditions which obtain in the Shahidan area. In the above method of mining adopted by the Chinese in Malaya the ground is not very hard nor are there such variations in the character of the different strata, as are seen in the Shahidan field. To work out the ore by means of small shafts only about 4 feet in diameter is impracticable if not impossible in the Shahidan area. The idea of sinking shafts of as small a diameter as possible is to make them stand for a long time without having recourse to timbering. Such small shafts are at times sunk every 50 feet and in some cases every 25 feet apart and the ore worked out from between the shafts and adjoining area by drives up the slope from the galleries which are situated at right-angles to the dip. In the Shahidan area the strata which would be met with are as follows :—

Alluvium.

Boulder bed, consisting of alluvium and large boulders of sandstone.

Shales with alternating flagstone bands some of which are very hard.

Conglomerate which is very hard and tough.

Because of the boulder bed and the flaggy beds of sandstone it would not be very easy to sink very small shafts. Another thing is that the shales when exposed to the action of rain and sun disintegrate very rapidly and one can't depend on a shaft in this area to stand for any length of time unless it be properly timbered. I therefore propose a modification of the above method which is that fewer and larger shafts should be sunk, the distance between each shaft to be about 400 feet instead of 50 feet which is the usual distance between the shafts in the Malayan tin mines. I suggest that shafts about 10 feet in diameter should be sunk. When properly timbered or lined with masonry the clear diameter of the shafts should be about 8 feet. Plenty of timber is available in the forest nearby and I am sure the work of timbering could very well be executed by local carpenters. It is necessary that timbering should be as cheap and simple as possible. It may also be found feasible to line the shaft with sandstone. There are sandstone quarries not very far from Shahidan. If the walling is done with stone and mortar there would not be much percolation of water either. The new workings should be in virgin ground. It would be necessary to leave a barrier of from 200 to 300 feet between the old workings and the new so that water from the old pits may not find its way into the new workings.

We will first suppose that a pit A is sunk 200 feet to the west of the line demarcating the worked out area from the unworked area. Another shaft B is sunk to the west of A, the distance AB being 400 feet. A third shaft C is sunk 400 feet to the south of the shaft B while a fourth shaft D is sunk to the east of C, the distance CD being 400 feet. It will thus be seen that the area ABCD with the four shafts A, B, C and D at its corners is in the form a square block 400′ × 400′. As the strata in the Shahidan area have a southerly dip the shafts A and B will be on the rise and the shafts C and D will be on the dip. The shafts C and D and A and B are connected by driving levels in an east to west direction, while the shafts C and B and D and A are connected by rises running in a south to north direction. From the level CD drives up the slopes are driven in a line parallel to CB and DA. The block ABCD having been thus opened up by a number of parallel drives all that remains to be done is to strip the ore-bed by the longwall mining method, so called because the mineral is worked away in long faces. In Germany the longwall method is very successfully used in the copper shale workings in the Mansfeld District. This copper ore is in thin beds usually from 3 to 5 inches thick. So far as the thickness of the ore is concerned there is a very close analogy between the occurrence of copper shale in the Mansfeld District and of the Panna diamond-bearing conglomerate whose thickness varies from 3 inches to about 18 inches in the Shahidan area. The longwall system is also successfully used in working out thin seams of coal. In this system the ore is stripped in long faces in successive cuts, the rubbish and over burden from the next cut being used to fill up the empty space produced by opening out the previous cut. Longwall may be advancing or retreating. In longwall advancing, mining begins near the shaft bottom and proceeds outwards forming a gradually widening and increasing length of face to the boundary. The passages are made through the excavated portions of the mines and are supported by means of timber and by pack-walls built of the debris produced in opening out the road. In longwall retreating, headings are first driven out to the boundaries of the property and the ore worked back towards the shaft. Longwall advancing and longwall retreating are sometimes combined in the same mine for the reason that by the longwall advancing method an immediate output of ore is secured to compensate for the longer time required in opening up the longwall retreating.

The idea of having as many as 4 shafts in an area 400′ × 400′ is to reduce as much as possible the underground carriage of the ore and unproductive stuff from the workings to the shaft bottom. In large mines where only two or three shafts are in use mechanical means are employed to transport the ore from distant workings underground to the shaft. The employment of machinery for underground haulage would raise the working expenses considerably and would also require a larger initial outlay of capital; with more shafts as suggested by me underground haulage may be dispensed with. The coolies can carry the ore in baskets to the nearest shaft or it may be conveyed in barrows. To draw up the ore from shaft bottom I would suggest the use of some simple device such as a windlass, or if the quantity of ore and material to be raised is fairly large a small winding engine may be used.

If more miners and coolies could be mustered, another block similar to ABCD can be worked by having two more shafts E and F 400 feet to the west of B and C respectively; the block thus formed would be BEFC, shaft E would be on the rise and shaft F would be on the dip. In a similar manner many more shafts could be sunk on the rise and dip, one set running in the same line as ABE and another in a line with DCF. When once the mine is opened up two or more lines of shafts would always be open, each new line being developed while the preceding one is being stopped from. It would not be economical to raise the ore at all the shafts; some of the shafts would be used as ladder shafts and some as air shafts. The soft shaly overburden would be broken first by picks; some of the flaggy bands of standstone would also be broken by picks. If such bands are found to be hard they may be broken with bars and wedges. To break the conglomerate it would be found necessary to use explosives. Such unproductive material as is found in excess of that required to form pack-walls may be sent to the nearest shaft in baskets if the distance is not very long or in barrows when the distance is considerable. In stoping there would be two distinct operations, *viz.*, stripping the overburden consisting mostly of shales and secondly breaking the conglomerate. To facilitate the transport of the conglomerate to the dip drive the first operation should be kept well in advance of the second. The best procedure would be to employ one shift in stripping overburden and the next shift in breaking the conglomerate.

When stripping the overburden timbering would be required to give support to the shaly roof. For this purpose jungle props about 6″ in diameter will have to be used with caps of split timber about 3′ long, 1″ thick and 6″ vide. The distance between two props will depend on the nature of the roof. When the overburden used as filling is thrown back from the next cut, the props can be removed and used for the next line of supports.

Dewatering the Mines.

The main drives running along the dip slope will naturally drain the water to the shafts situated further to the south as the workings progress. The levels must be given a grade of 1 in 100 in the direction of one of the shafts which should then be used as a pumping shaft for that particular block. By leaving a barrier of 200 to 300 feet between the old and the new workings it is possible to reduce the percolation from the accumulated water in the old workings. If even with such a barrier the new workings are found to drain the old ones it would be best to drive a drainage tunnel between the old and the new workings to collect the water from the latter to a permanent pumping station. In that case some form of power pump would have to be employed. A direct-coupled pumping unit in which the centrifugal pump and the oil engine for driving it both have a common shaft would serve the purpose well. It could be removed to each successive line of shafts as the workings progress further towards the dip. If there is not much percolation from the old workings a double whim with two buckets running on wire-guides and with valves to make them self-acting should be employed. With one pair of bullocks a considerable quantity of water can be raised by such an arrangement. During the operation of sinking a shaft a large bucket or kible to raise the water would be found quite sufficient.

CHAPTER XIII.

SUGGESTIONS REGARDING IMPROVED METHODS OF WORKING THE DETRITAL AND ALLUVIAL DEPOSITS.

Detrital deposits.

Detrital deposits such as those occurring at Ranipur, Bhawanipur, Srinagar and Niranpur would best be worked by opencut methods. At all the four places mentioned above, the ground has been literally riddled with shallow pits in a haphazard way to such an extent that it would be difficult and uneconomical to get at the gravel and shaly conglomerate still lying intact between the old pits. To the south of the worked-out area a long trench should be cut parallel to the outcrop leaving a barrier of about 20 feet. The barren overburden consisting of soil and decomposed shale should be stripped off and dumped into the old pits further away. This method could only be adopted if either the State worked the detrital deposits departmentally or allowed only one party to work at any particular place. If the Panna Durbar had put a stop to all irregular working in places like Bhawanipur, Ranipur and Srinagar and had introduced the simple but systematic plan of working suggested by Vredenburg as far back as 1905 an enormous amount of waste would have been stopped. Unfortunately the mines were allowed to be worked in haphazard and unsystematic ways which have been the subject of adverse comment by many observers like Rousellet, Franklin, Medlicott, King and others. The Bhawanipur and Ranipur mines having been practically despoiled by the miners they began latterly to attack the detrital deposit at the Niranpur mines which are a southerly extension of mines formerly known as the Harduapur mines. This bit of ground was ideal for working according to the systematic plan so clearly explained by Vredenburg on pages 310 and 311 of the Records of the Geological Survey of India Vol. XXXIII.

It appears to me that the Panna miners have all along been so indulgently treated that by persuasive measures it is not possible to induce them to work in a systematic way. The State will have to frame strict rules for mining systematically and the officer in charge of the mines will have to see that such rules are properly carried out. During the period of my stay in Panna I had explained to the miners the necessity of working according to a definite plan but as long as one and the same field is worked by a number of men all working independently it is not very easy to keep to a systematic plan of working. I therefore suggest that one field, say for example, Niranpur, may be leased to one party who would be held responsible for the systematic working of the same on approved lines. At present any one is allowed to work anywhere, the assigning of plots being left to a petty official known as a Jemadar. The miners work where they like and wash and treat the conglomerate when it suits them best. Some old heaps of conglomerate mined years ago are lying unwashed and untreated even at the present day. To return to the main point of working the detrital deposits properly. Long trenches would have to be cut parallel to the outcrop. These would be given a suitable grade so that all the water which percolates through the workings may be carried to one point where it would be pumped out. The next trench would be cut parallel to the first and the waste material from it would be dumped into the empty space left by the first trench. Trench after trench may thus be cut year after year. It is not late even now to begin work on the above lines.

Alluvial deposits.

The most important alluvial deposits are those of Itwa, Babupur and Sirswahi in the Baghen valley. Here also I would advocate working in a long face the full width of the deposit, and not by means of small pits sunk in different parts. The same remarks which I made regarding the working of the detrital deposits apply with equal force to the working of alluvial deposits also. The miner without any capital will either have to leave the field or else will have to work under others. The drawbacks to the leasing out of small claims to men without sufficient capital are several :—

1stly. Mining on a systematic plan cannot be properly enforced.

2ndly. Treatment of the ore by improved methods is impossible.

3rdly. Supervision becomes more and more difficult as the claims are scattered far and wide.

4thly. There is always a considerable risk of loss of diamonds by peculation in the absence of a central treatment plant.

In the alluvial workings the diamond-bearing gravel occurs at variable depths. In Itwa the depth at which the gravel occurs varies from 20 to 30 feet and even more according to the situation of the deposit. The workings should be in the form of a long face and should be worked in successive cuts. The overburden would have to be taken off in two or more layers depending on the depth at which the gravel occurs. To avoid carrying the overburden and gravel all the way up from below light trestles made of jungle wood would have to be used. The principal advantages of working the alluvial deposits in a long face as suggested above are the reduced cost of operations and the better treatment of the diamondiferous gravel leading to the better extraction of the diamonds.

In my opinion a central treatment plant for screening and concentrating the diamond-bearing gravel should be installed at the earliest opportunity at Itwa. For this purpose I would recommend a small diamond-washing plant similar to one designed by Messrs. Chatteris Engineering Co., Ltd., of Chatteris, Cambs, England. Fig. 44 shows the general arrangement of this plant and a brief description thereof will be found in the chapter on the treatment and concentration of the diamond-bearing conglomerates and gravels. If alluvial mining is attempted on a large scale it would be worth while installing a small grease-table or a greased frue-vanner to separate the diamonds from the concentrates automatically. (See Fig. 21, Plate XVI.)

In out-of-the-way places, far from a treatment plant, one or two small washing pans and a few swinging sieves of the proper size and mesh might be installed. At present, no screening of any kind is resorted to in any of the mines in Panna. It is essential to eliminate as much of the barren material as possible before puddling. For this purpose two swinging sieves should be used, the top one having a $\frac{1}{2}''$ mesh and the bottom one $\frac{1}{8}''$ mesh. The plus $\frac{1}{2}''$ material, *i.e.*, material which does not pass through the $\frac{1}{2}''$ sieve is examined for large diamonds and then thrown away. Similarly the minus $\frac{1}{8}''$ material, *i.e.*, all the stuff which passes through the $\frac{1}{8}''$ mesh is thrown away.

In the case of gravel which is wet it would be necessary to dry it in the sun before screening it. My experience is that there are not many diamonds in the alluvial gravels which cannot pass through a ½″ mesh. A few may be encountered with occasionally. It would be best to treat the minus ⅛″ material separately in a washing pan, occasionally, to find out if there are any smaller diamonds in the concentrate. The −½″ and +⅛″ material would be treated on one or more rotary washing pans. The concentrates obtained from the washing pans would be sorted out on canvas covered tables. Messrs. Fraser and Chalmers of Erith, Kent, England, have designed a rotary hand washing pan fitted with a conical trommel which may be made of any suitable mesh. (Fig. 20.)

CHAPTER XIV.

THE ECONOMICS OF THE PANNA DIAMOND MINES.

The value of a diamond mine depends on five factors:

1. The price realized for the diamonds.
2. The grade of the diamond-bearing rock.
3. The amount of diamond-bearing rock within it capable of exploitation.
4. The cost of production and the margin of profit.
5. The rate of production.

The first three points have been discussed in detail in another part of this report. It will, therefore, be sufficient to give a summary of these points.

Price realized for Panna Diamonds.

The price realized for Panna diamonds depends naturally on the demand for these diamonds at the time of sale. This demand varies from time to time. In the diamond trade as in other trades, there are periods of "boom" and periods of depression depending not only on the greater or less demand for diamonds but also on the rate of production. The South African Diamond Mines being the largest producers of diamond in the whole of the world, the price of the diamond is regulated by the rate of production from these mines. The output of diamonds from the Panna mines is insignificant in comparison with the enormous output of diamonds from the mines in South Africa. The world's prices of diamonds are therefore regulated by the demand for diamonds on the one hand and by the rate of production of diamonds of the South African mines. It must be stated, however, that there is always a fair demand for Panna diamonds in India judging by the fact that higher prices are paid carat for carat for the Panna stones than for the South African diamonds.

The average price realized for the Panna diamonds from July 1917 to June 1928 works out at Rs. 117 per rati for all stones under 6 ratis. The price realized for the Shahidan diamonds during this period was Rs. 136 per rati and that for the Itwa gems Rs. 82 per rati. This difference is due to the fact that the Itwa diamonds are as a rule smaller than the Shahidan diamonds. The price realized for the Shahidan diamonds in 1918-19 was Rs. 154-12 per rati while that realized for the Itwa diamonds during the same year that is July 1918 to June 1919 was Rs. 89 per rati. The price obtained for the Shahidan diamonds in 1904 was only Rs. 43 per rati. We thus find that the prices keep on fluctuating. At present, the price obtained for the Shahidan diamonds comes to about Rs. 100 per rati and for the Itwa diamonds about Rs. 65 per rati.

The prices quoted above are average prices for all diamonds, good, bad, and ordinary produced in the Shahidan and Itwa mines and for sizes below 6 ratis. The following few extracts from the sale register of the Panna diamond mines will give an idea of the value of good diamonds found in Panna State. These diamonds were produced in December 1919, and January, February, March and April 1920 :—

Quantity.	Produced in.	Weight.	Value realized for the diamonds	Value per rati.
		Rati. Besi.	Rs.	Rs.
1	December 1919 ..	2 9	357	146
1	Do. ..	2 10	407	163

Quantity.	Produced in.	Weight.		Value realized for the diamonds	Value per rati.
		Rati.	Besi.	Rs.	Rs.
1	December 1919 ..	1	18	269	142
1	Do. ..	1	5	240	182
1	Do. ..	3	19	1,501	380
1	January 1920 ..	3	0	906	302
1	Do. ..	1	17	555	300
1	February 1920 ..	1	12	334	209
1	March 1920	2	1	364	178
1	Do.	1	1	204	195
1	Do.	1	5	275	220
1	April 1920	3	19	2,077	526

That the quality of some of these diamonds must have been very good goes without saying. A stone in the natural state when cut in the shape of a " brilliant " loses nearly two-thirds of its weight in the process of cutting and polishing, particularly if the crystal be of the hexoctahedron class and globular. The stone weighing 3 ratis and 19 biswas mentioned last in the above list must, when cut and polished, have been reduced to about 1 rati and 6 biswas. For this stone Rs. 2,077 were offered which fact speaks very well for the quality of that particular stone.

2. The grade of the conglomerate :—It has been shown on a previous page that the grade of the Shahidan diamondiferous conglomerate is 0.036 according to one method of calculation and 0.047 according to another. In my opinion when a centralized treatment plant is installed the grade of the conglomerate will be found to be well over 0.04. I have therefore taken this latter into consideration in the calculations regarding the margin of profit in working the Panna conglomerate.

3. Quantity of workable diamond-bearing rock:—I have shown in a previous chapter that out of the total diamondiferous area of 90 square miles near Panna, Majgawan, Itwa, Barghari and Bijepur at least 5 square miles of a rich diamondiferous area could surely be depended upon. The yield of the diamonds from the 5 square miles would be 5,575,672 ratis, if the grade were reckoned to be 0.04. This means that there is enough material to work upon for a number of years which would justify the investment of a fairly large capital.

4. The cost of production and the margin of profit:—The cost of production varies within very wide limits at different mines. From some mines it is quite easy to work the conglomerate or the gravel. In others it is difficult. The situation of the mine, the depth of the workings, the presence or absence of hard flaggy bands and the dry or wet nature of the workings have all to be taken into consideration. The cost of working is highest in the deep mines of Shahidan. I have noted that the larger the diameter of the pit, the greater is the cost of mining a cubic foot of conglomerate than in the case of a smaller pit of the same depth. Experienced miners mostly sink pits of moderate dimensions and take out as much conglomerate as possible by driving underground radiating galleries all round. The cost of mining the hard conglomerate (*muddha*) and treating it varies from Re. 1-4-0 to Re. 1-12-0 per cubic foot of conglomerate. The latter figure is true only for very large and deep mines say more than 35 feet in diameter and from 55 to 65 feet deep, where the size of boulders is so large that they have to be blasted, where the flaggy bands occur more frequently and are very hard and where the percolation of the water from the old working is so great that small power pumps have to be employed.

At the present day the rate of daily wages is annas five per day for men and annas three per day for women. The latter however usually work on a sort of contract basis. They get one pice for removing 8 basketsful of the broken ground from the mine to the surface. Most of them earn annas four per day in this way. I have therefore reckoned the wages of women at annas four per day.

The following shows the cost of sinking a pit 40 feet in diameter and about 60 feet deep :—

	Rs.	a.	p.
Excavation.			
25 men at annas five per day for a period of six months ..	1,406	4	0
25 women at annas four per day for a period of six months	1,125	0	0
Washing.			
15 men working half time at $2\frac{1}{2}$ annas per day for four months	281	4	0
15 women working half time at two annas per day for 4 months	225	0	0
Pumping charges for a small centrifugal pump worked by an oil engine	360	0	0
Gun-powder for blasting boulders, fuel for heating the conglomerate, tools, baskets, sundries for pumping plant.	250	0	0
	3,647	8	0

The total conglomerate which can be mined from a pit of the size mentioned and from a few galleries driven underground would be at least 2,000 cubic feet, if not more, supposing the conglomerate to be one foot thick. If we take the grade of the conglomerate to be .04 rati per cubic foot of conglomerate it would mean that diamonds weighing 80 ratis would be obtained after crushing and washing the conglomerate.

As stated before, the price fetched for one rati weight of diamond on an average is Rs. 100 at the present day. The proceeds from the sale of the 80 ratis would be Rs. 8,000.

	Rs.	a.	p.	Rs.	a.	p.
Value of diamonds produced				8,000	0	0
Royalty at 25 %	2,000	0	0			
Cost of working in round figures..	3,650	0	0			
	5,650	0	0			

The net profit therefore would be Rs. 8,000 minus Rs. 5,650 = Rs. 2,350.

It should be remembered that the rate of Re. 1-12 for mining and washing 1 cubic foot of the conglomerate is the maximum rate when the ground presents unusual difficulties and when the percolation of water is very great. When mining is systematically carried on by one large concern and when underground methods of mining are used the cost is bound to be less. On the other hand washing and concentrating the conglomerate by machinery may increase the cost of washing and treating the ore. I think the rate of Re. 1-8 per cubic foot for mining and treating the conglomerate will be found quite ample when the mines are systematically worked either departmentally or by a company.

Rate of Working.—We have already seen that 50 men working for 6 months in a year can mine at least 2,000 cubic feet of conglomerate. One man can therefore mine 40 cubic feet of conglomerate in 6 months or 80 cubic feet of conglomerate in a year. The output per person could easily be doubled by introducing systematic mining methods. One man can under improved conditions of working mine 160 cubic feet in one year. If 2,000 men could be mustered and if they could be made to work for 300 days in a year the total quantity of conglomerate produced would be 2,000 × 130 equal to 260,000 c.ft. which is equivalent to 260,000 × .04 ratis, taking the grade of the conglomerate to be .04 rati per cubic foot, equal to 10,400 ratis.

I have stated before that the average price fetched at present for one rati by weight of diamond is Rupees 100. When production increases the price may probably go down. Supposing the price falls to Rs. 75 per rati, the gross income from the above yield would be 10,400x75 equal to Rs. 780,000.

In the calculations which follow I have assumed the royalty to be 25 per cent. on all the diamonds produced. The present rates of royalty for the Shahidan deep mines are as follows :—

1 to 5 ratis	20%	royalty.
5 to 10 ratis	25%	„
Above 10 ratis	67%	„

According to the present rules all large diamonds above 10 ratis become the property of the Durbar, the mine-owner getting 33 per cent. by way of prize-money.

As diamonds above 10 ratis occur only occasionally I have taken an all-round rate of 25 per cent. for royalty which I think will be found quite ample. When mining operations are carried on intensively the number of diamonds below 5 ratis will be considerably in excess of diamonds above 5 ratis and I think the royalty will not work out at more than 25 per cent. except occasionally when a number of large diamonds above 10 ratis are found.

Reverting to our calculations, the royalty which would have to be paid on Rs. 7,80,000 worth of diamonds would be Rs. 1,95,000 at 25 per cent. Working costs at Re. 1-8 per cubic foot of conglomerate would mean an expenditure of Rs. 3,90,000 on that head. To these, there should be added Rs. 75,000 for depreciation, &c. The net profit in one year therefore would be as follows if 2,000 labourers could be mustered to work on the mines :—

260,000 c.ft. of conglomerate produced in one year.

At .04 rati per cubic foot the weight in ratis of the total output of diamonds during one year would be 260,000 × ·04 equal to 10,400 ratis equal to Rs. 780,000 at Rs. 75 per rati.

Therefore, the net proceeds from the sale of diamonds is equal to Rs. 780,000.

Less—

	Rs.
Royalty at 25% on the total value	195,000
Working cost at Re. 1-8 per cubic foot of conglomerate ..	390,000
Depreciation, &c.	75,000
	660,000
Net proceeds	780,000
Less ..	660,000
Net profit	120,000

There is therefore plenty of scope in the conglomerate alone for a business of considerable size, as there is a fair margin of profit involved.

5. Rate of production. —When diamonds are produced at a considerably faster rate than they are produced

at present, the prices realized for them will naturally go down to a certain extent as there would not be the same competition for buying very good stones as is the case at present. However, as stated before, the output of diamonds from the Panna State even at its best would be insignificant in comparison with the enormous amounts produced by the South African mines and therefore the decline in prices of the Panna diamonds would only be small.

CHAPTER XV.

SUGGESTIONS REGARDING IMPROVEMENT IN THE TREATMENT AND CONCENTRATION OF THE DIAMOND-BEARING CONGLOMERATES AND GRAVELS.

The present-day treatment and concentration methods described in previous pages are very primitive and there is urgent need for a central treatment-plant, one in Panna and one in Itwa, at least for the present, to replace the methods at present in vogue.

Diamond is a commodity which could easily be stolen and even if the strictest supervision were kept over the men engaged in the operations of crushing, washing and picking out it is impossible to prevent the theft of diamonds.

Suitable concentrating machinery would have a two-fold beneficial effect. In the first place it would prevent the peculation of diamonds and secondly it would increase their output because, by the present primitive methods used, it is not possible to recover all the diamonds.

The following two English Firms have specialized in the manufacture of concentrating machinery :—Messrs. Fraser and Chalmers of Erith, Kent, and Messrs. the Chatteris Engineering Co. of Chatteris, Cambs, England. The concentrating devices made by both these firms are used in some of the diamond mines of South Africa. There may be some firms in South Africa also who are experts in the manufacture of such machines but I have no knowledge of them.

The following machinery would be required for a concentration and treatment plant if it is intended to work the mines systematically on a fairly large scale.

Crushing Appliances.—Some authorities on the subject of diamond concentration-plant hold that appliances in which the ore is crushed by impact should, as far as possible be avoided because though the diamond is the hardest substance known, still, it is brittle and a sudden blow would break it. For this reason they advocate gyratory crushers of a special type known as the Gates type. However, where the diamond-bearing rock is very hard as in the case of the Panna conglomerate, I think a reciprocal jaw-crusher would give the best results. It is, moreover, simpler to operate. Some of the slabs of the conglomerate when got out from the mine are very thick and rather large and I think it would be found necessary to instal two crushers in tandem. In the first, the large pieces as they come out from the mine would be fed. The product from this would go to the second crusher which may be set to any degree of fineness required. This would do away with preliminary hand-breaking which gives opportunities for theft. In many South African diamond mines rolls or disc-crushers are used but for our purposes two rock-breakers should yield satisfactory results. For the diamond-bearing gravel, kakru, I would recommend a pair of rolls in preference to a rock-crusher of the jaw type.

Jigs and Pans.—Two different concentrating devices are used in South Africa for the concentration of the crushed ore. One of these is known as the jig which consists essentially of a plunger compartment which communicates on one hand with a screen box and on the other by means of an ordinary flap valve with a large water launder which is kept filled to a certain level. The crushed conglomerate would be put in a screen box which consists of a steel tray fitted with a screen made of punched steel plate with round perforations. The diameter of the perforations varies from $1\frac{1}{8}$ inch in the coarse jigs to $\frac{3}{4}''$ in the fine jigs. The bottom bed consists of spheres of a special alloy of copper and aluminium having a specific gravity of 3·4 and of a slightly larger diameter than the perforations. In some jigs steel punchings are used instead. The crushed diamond ore is distributed uniformly across the head of the screen by a feed chute and subjected alternately to the action of ascending and descending currents of water produced by the up and down movements of the plunger which is worked by an eccentric and makes about 120 strokes per minute. The result is that the heavy particles, including coarse diamonds, gradually work their way through the bottom bed of the punchings into the hutch while the lighter constituents of the rock are carried over the discharge end of the screen box.

For the Panna conglomerate I recommend the jig for concentration in preference to the washing pan. For the gravel (kakru) and for the shaly conglomerate (gilta and ranjka) I advocate the use of the washing pan because exhaustive tests in South Africa have proved that where the crushed material is clean a jig gives the best results while a washing pan gives the best results when the material to be treated contains a certain percentage of clayey matter.

PLATE XV.

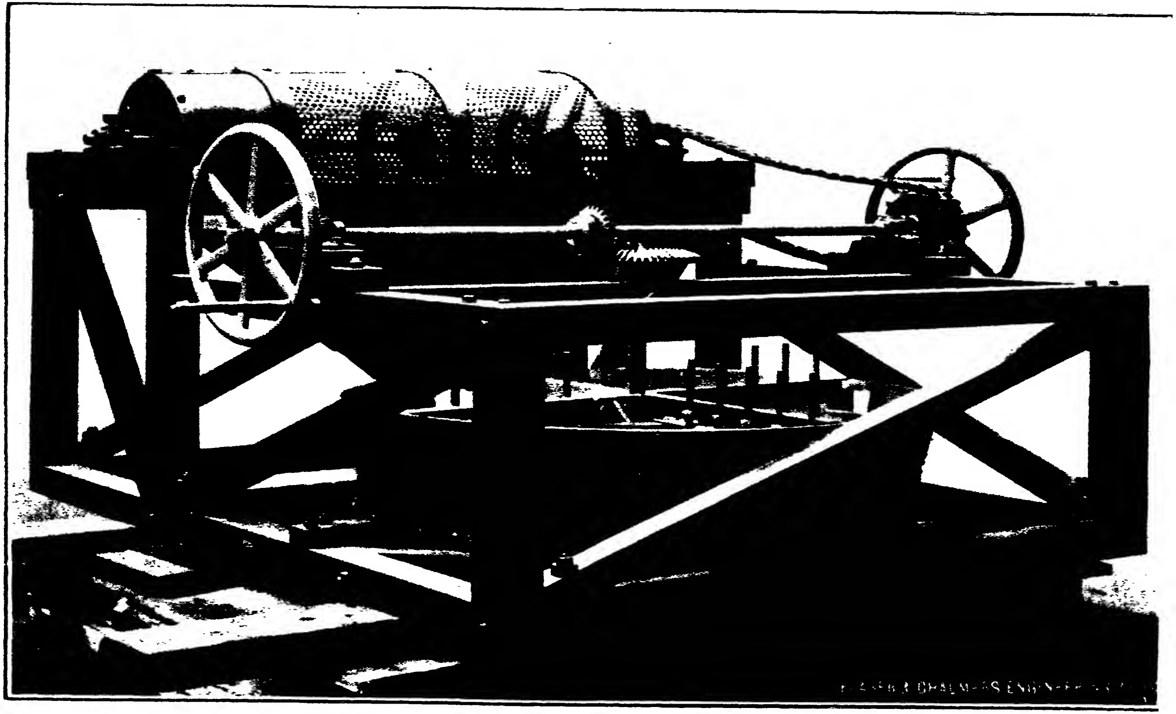

FIG. 20.

Hand-operated diamond-washing Pan manufactured by Messrs. Fraser and Chalmers of Erith, Kent, England. A conical revolving trommel also operated by hand is shown fitted to the wooden frame in the above photograph.

The diamond washing pan or the rotary washing machine as it is otherwise called consists of a shallow annular iron pan from 5 feet to 14 feet in diameter and 16 inches to 2 feet deep externally and an inner rim from 18″ to 4′ in diameter which is 6 inches deep. In the centre is a revolving vertical shaft carrying a number of radial arms from 8 to 12 in number each provided with vertical blades which dip into the ore fed and stir it up as they revolve. The stuff is fed in at the outer circumference and the muddy water escapes over the low inner rim of the stirring pan. The teeth or stirring knives are so shaped and arranged as to bring the heavy gravel towards the circumference. The stirrers are run at a speed of from 8 to 14 revolutions per minute, depending on the size of the pan. The overflow from the pan is fed into another pan to catch any diamonds which may by chance have escaped in the first operation. When the pan has been at work for 10 hours a sliding door is pulled out at the bottom through which the gravel falls in a truck or receptacle placed underneath, as it is drawn round by scrapers attached to the arms. A large pan can treat 300* loads per day of 10 hours and yields about 3 loads of gravel. The hand-operated 5 foot pan which has been already installed at Niranpur is capable of treating 14 loads in 10 hours.

The trommel is an appliance used for the purpose of sizing any crushed ore to the required grade. It is a machine sieve. Such sieves are of two kinds ; flat oscillating sieves and revolving conical, cylindrical or spiral sieves. Such sieves are often called trommels because they are drum shaped. They are made of woven wire-cloth, of punched-sheet metal either iron, steel or copper or are

* One load equals 16 cubic feet.

made of a series of parallel bars. The perforated plate or wire-cloth is bent into the required conical or cylindrical form and supported by arms to the central axis. The conical trommel has the advantage that its axis can be placed horizontally, for the slight inclination of the sieves causes the mineral to make its way from the feed or smaller end to the discharge or larger end provided that the machine is in motion. If the trommel is cylindrical, its axis must be inclined in order to secure the same result.

For a very small treatment plant just for prospecting purposes large swinging sieves operated by the hand would give good results but for a permanent plant, a trommel is a necessity. By arranging the perforated plates with different openings three or more sizes could be made.

Hartz Jigs.—For treating the concentrate made by the washing pans and jigs single compartment Hartz jigs are employed in South Africa.

Circular Hand Sieves.—At the smaller mines the concentrate made by the hartz jigs is always subjected to a final concentration by hand jigging before the separation of diamonds is attempted. This operation is usually performed in a small circular hand sieve which is moved rapidly up and down in a tub of water and at the same time given a slight swishing movement. By this movement the diamonds are caused to gravitate to the centre of the sieve and upon inverting the latter upon a canvas covered table they are found on the top of the central portion of the heap thus formed and simply picked out by hand.

Grease Table.—The final separation of the diamonds from the other concentrates is performed at all the important mines in South Africa by a mechanical contrivance known as the Grease Table. The process depends upon the fact that diamonds stick to grease more rapidly than other minerals. Consequently if the concentrate from the jigs which contains in the South African mines many minerals beside diamonds such as magnetite, titanic iron, pyrites, olivine, etc., is washed down on inclined plane covered with a thin layer of grease, the diamonds adhere and the other minerals are washed off. This can be expressed in other words by stating that the surface tension between the diamonds and grease on the one hand and between diamonds and water on the other is greater than the surface tension between water and grease whereas in the case of the heavy minerals the surface tension between these minerals and water is greater than that between the minerals and the grease.

The grease generally used is a kind of crude vaseline known as petroleum jelly. Certain kinds of grease have been found to give much better results than others and a grease which is found to give the best results at one mine has been found very unsatisfactory at others. This may probably be due to the different chemical compositions of the waters used at the different mines. It is also noteworthy that diamonds obtained from the treatment of yellow ground in South Africa do not adhere to the grease so well as those from the blue grounds.

The following descriptions of the grease-tables and greased frue-vanners used in Kimberley are taken from Wagner's "Diamond Fields of Southern Africa."

The grease-tables employed at Kimberley are 7 feet long and 28 inches wide. They consist of finely corrugated metal plates set in a light frame which is suspended by steel laths from vertical supports so as to have a downward inclination of about 7½ inches in the direction of its length. The upper and lower plates are respectively 2 feet 6 inches and 4 feet 6 inches in length and between them there is a drop of about 1 inch. The plates are covered with a thick film of grease applied by means of a wooden spatula. The table is shaken rapidly from side to side by an eccentric which makes 252 strokes per minute. The length of the stroke varies from ¾ inch for fine concentrates to 5/16 inch for coarse concentrates. In order to avoid all possibility of losing valuable diamonds two tables are generally arranged in series. The concentrate is uniformly distributed across the head of the upper table by means of a corrugated feed roll and carried down to the plates by a stream of water from a trough, the tailings being discharged on to the head of the lower table. Most of the diamonds are found to adhere to the top end of the upper plate of the first table which has to be dressed twice per 10 hours shift, since the grease loses its property of catching diamonds after a few hours due to becoming gradually mixed with particles of water. The lower plate is dressed once per shift while the second table is dressed once every second day in summer and twice a week in winter.

The material scraped off the table is put into small cylinders constructed o finely perforated steel plate which are immersed in a tank of boiling water. The grease rises to the surface of the water from which it is skimmed off and used over again. The concentrate is cleaned in a boiling solution of caustic soda and dried. Such a concentrate in the South African diamond mines consists of diamonds, grains of ilmenite and pyrite, besides bits of copper derived from detonators used in the mines. The finer concentrate is passed over a Wetherill magnetic separator which gets rid of ilmenite and pyrite both of which being magnetic are drawn towards the magnet and deflected in their course. The coarse concentrate goes direct to the sorters who pick out the diamonds from the valueless stuff.

Greased Frue-Vanners.—Although the grease table is a very efficient machine there are two drawbacks to its use. Firstly, the grease has to be applied by hand which cannot be done very uniformly with the result that some part of the table is effective while some is not. The scraping off also has to be done by hand which means that there is considerable risk of loss of diamonds by theft. Secondly, diamonds caught by the grease are exposed for long periods. These disadvantages are done away with in a greased frue-vanner. A frue-vanner is well known as a device in which an endless belt of India-rubber cloth of a suitable length and breadth is supported by a frame with a number of small rollers on which it travels easily and it is driven slowly in a direction opposite to that in which the belt tilts. Grease is applied continuously to this belt by means of a perforated grease drum fixed below the frame. the thickness of the film being regulated by a wooden scraper. The belt is run to make about 3 revolutions per hour so that the coating of grease is renewed once in every 20 minutes. The concentrate is fed on to the vanner at the usual place by means of a corrugated roll extending right across the belt. The material adhering to the grease is carried to the head of the vanner where it is automatically scraped off by means of a wooden bar while the worthless concentrate is carried over the lower end of the vanner into a tailing launder by means of water fed on to the belt by pipe sprays. The diamond-bearing concentrate adhering to the grease falls into a chute of iron which is heated from below by electric coils. The melted grease is separated from the concentrate by allowing it to fall in a suitable vessel, while the latter is allowed to collect in a special receptacle made of perforated steel. To prevent unauthorised persons from interfering with the concentrate the vanner as also the vessel for the concentrates, both are enclosed in a wire cage. This prevents the peculation of the diamonds. (Fig. 21, Plate XVI.)

The above gives a general idea of the principal machines used in concentrating the diamond-bearing ore. The size of the plant, the number of crushers, rolls, jigs, trommels, and pans required and other details can be worked out to suit the daily output from the mines. A direct-treatment concentrating plant capable of dealing with about 150 tons per day would cost from £12,000 to £15,000. A large amount of water would be required so that it would be advisable to have a storage tank having a capacity of 20,000 gallons and a pumping plant. Fortunately for a central treatment plant in Panna the requisite amount of water could easily be obtained from the Lokpalsagar tank.

Treatment plant for diamondiferous gravels.

Figure 44, Plate XXX, gives an idea of the general arrangement both in plan and section of a small diamond-washing plant consisting of the following parts :—

1 Grizzley.
1 Ore-crusher.
1 Crushing rolls.
1 Revolving trommel.
1 Feed elevator.
2 Diamond-washing pans so arranged that one of them is at a higher level than the other.

PLATE XVI.

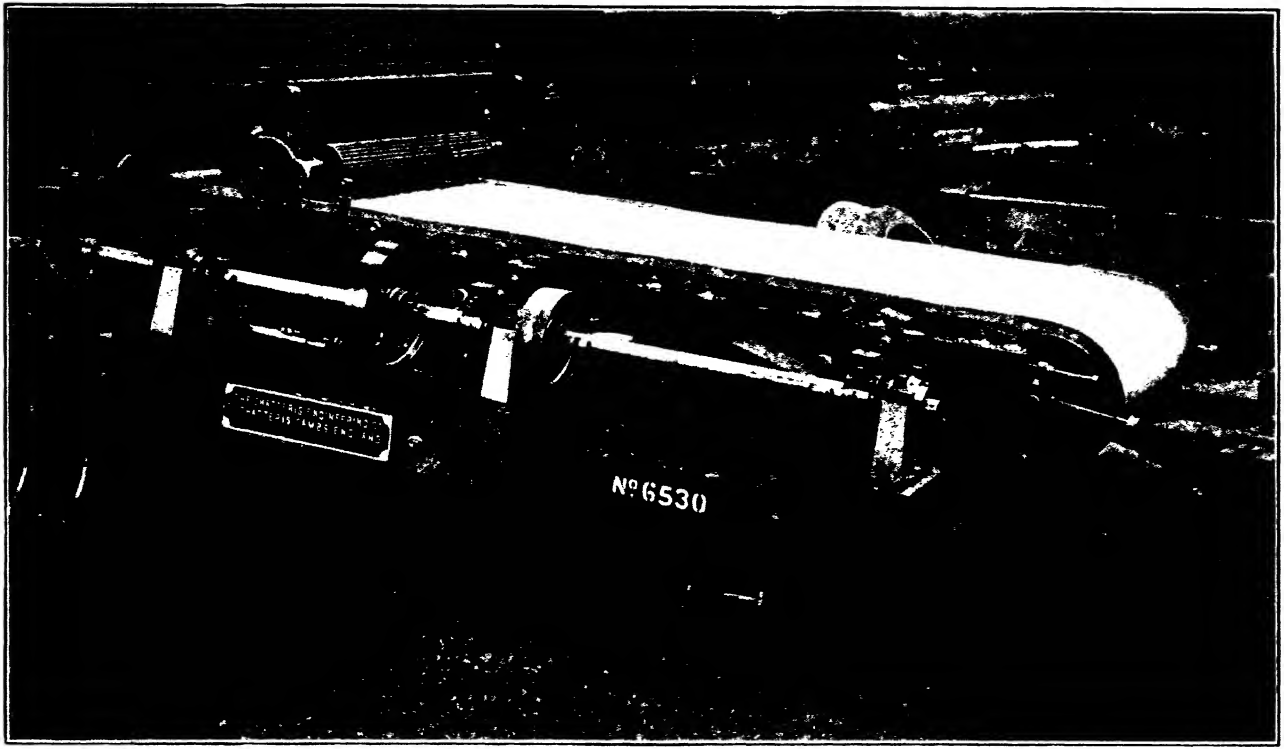

FIG. 21.

Greased Frue Vanner for automatically separating the diamonds from other heavy minerals in the final concentrates.

1 Tailings elevator.
1 Portable engine and loco type semi-stationary boiler.
1 Centrifugal pump.
1 Water tank.

The Steam Engine works the stone-crusher, rolls, the revolving trommels, both the washing-pans and the feed and tailing elevators through the medium of suitable shafting and belts.

The crude ore is fed on to the grizzley. The smalls which fall through the bars go to the crushing roll direct from a special chute while the coarser material goes to the crusher. The crushed material from the jaw-crusher also goes to the rolls. The product from the crushing rolls goes to the feed elevator and from there to the revolving screen giving two sizes, the under-size for washing pan and over-size to dump for hand-sorting if necessary. The mud and tailings from the first washing pan go to the second washing pan. The worthless tailings from the latter are raised by the tailings elevator and discharged on to the tailings dump.

The grizzley, the stone-crusher and rolls are separately mounted while the whole of the washing plant including the two pans can be supplied, by the makers, fitted on wheels for transportation. The elevators are in this case mounted outside and are pivotted near the top so that they can be swung upwards when being moved. This plant is in my opinion very well suited for use where the diamond-bearing ore is a gravel.

Treatment plant for diamond-bearing conglomerate.

The following is a rough outline of a suitable treatment plant for concentrating the diamond-bearing conglomerate (muddha):—

One grizzley 6′-0″ × 2′-6″ with steel taper bars spaced 1½″.

One chute to convey oversize from the grizzley to the ore-crusher.

One 10″×7″ ore-crusher set to crush to $1\frac{1}{2}$″ size.

One trommel with $\frac{5}{8}$″ holes.

One crushing rolls set to crush to $\frac{5}{8}$″.

Set of coarse jigs.

One dewatering screen.

One crushing rolls set to crush to $\frac{3}{8}$″.

Set of fine jigs.

Hartz jigs.

Greased frue-vanner enclosed in a locked wire-cage.

The ore as it comes from the mine is thrown on the grizzley. The oversize from the grizzley is conveyed to the ore-crusher which is set to crush to $1\frac{1}{2}$″. The crushed product as also the undersize from the grizzley are both conveyed to a trommel having $\frac{5}{8}$″ diameter holes. The oversize from the trommel goes to the first rolls set to crush to same size as the holes in the trommel, *viz.* $\frac{5}{8}$″. The undersize of the trommel and first rolls is conveyed to the battery of coarse jigs. Tailings of the coarse jigs go to 1-16″ dewatering screen. The oversize of screen goes to 2nd rolls set to crush to $\frac{3}{8}$″. Undersize of screen and the product from the 2nd rolls go to the battery of fine jigs. The crude jig concentrates are then treated on Hartz jigs and the concentrates of the Hartz jigs are taken direct to a greased frue-vanner enclosed in a wire cage.

Dr. Oscar Weigel's suggestions for a treatment plant.

Dr. Oscar Weigel, Professor of Mineralogy in the University of Marburg, Germany, had visited many of the Panna diamond mines in November 1927. He was very interested to see the different diamond workings. After his visit to the Burma Ruby Mines in the Mogok district he wrote to me a letter on the 15th March, 1928, in which he particularly drew my attention to the system of mining and concentrating the ruby-bearing gravels. The following is a description in Dr. Weigel's own words of the mining and concentrating methods at present being used by the Ruby Mines Co., in Mogok and which he thinks would be quite suitable for the Panna gravels after some necessary modifications :—

" There, in Mogok, I have seen a treatment of the gem-gravel and byon-deposits which, with a few changes, would be quite suitable for your diamond mines. Some years ago, they had here concentration plants just of the kind you showed me in blue-prints ; rotating sieves, jigs, pans, etc. They have discarded this system as too expensive and not giving very satisfactory results because, it makes stealing relatively easy. Now, all these plants are scrapped. I think they had at one time thirty such small concentration plants some of which are now under water in the big old mine which was flooded about 3 years ago by an earthquake. The following scheme is used at present. The byon or gravel which is worked loose by monitors falls under a stream of water in a channel and is carried down to the sucking end of a gravel pump ; this pump throws the gravel against an iron grate which retains the large rock-pieces. The gem-bearing gravel then flows down through a common sluice box with 4 boxes of which the two in the middle usually contain all gems. The boxes are of such size that 12 hours' work fills them up. The gravel is conveyed by means of a stream of water to rotating sieves having three or four different meshes. Up to this point all working and transport goes on under the surface of water so that the workmen do not see anything of the gravel and therefore are unable to pick out any gem.

From the sorting sieves the gravel is taken out under the supervision of a reliable European officer by men wearing large masks of perforated iron to prevent their swallowing any stones. It is then put in hand-sieves which are moved rapidly up and down in an iron tank which is so deep that no man can reach its bottom and get any gems which he may purposely drop down from the sieve. After washing for some minutes under the control of the officer the men spread out the contents of their pans on a table covered with a sheet of iron. The officer then closely examines it to see if there is any big gem. The gravel is transferred back to the hand-sieve and washed a second time, after which it is examined carefully by native workmen who have to wear masks. The officer (often the Manager himself or his son) supervises the operations carefully. The workmen have strict instructions to sort out all stones which may bear the faintest resemblance to the ruby. Every spinel or garnet of whatever colour has to be selected so that the workmen may have no excuse whatsoever for not selecting a stone on the ground that it seemed worthless to him. As soon as a gem-stone is picked out it is put in a steel box with a small circular hole in it. When the sorting operation is over the steel box is taken by the officer to the General Manager's office who personally inspects the contents after which the sorting of the stones for commercial purpose is done by specialists. Usually two sorting tables and one washing tank are supervised by one reliable officer."

"In one mine—the best sapphire mine—two jigs are used after the sluice box. Perhaps it would be safer for you also to use a few jigs after the sluice box. Very important for the Panna gravels, more than for the Mogok gravels, is the proper use of sieves. Because the diamonds are never of very big size and seem always to become perfectly free from the rock in which they are cemented it should be possible to concentrate to a high degree merely by sieving."

"This very simple and cheap treatment gives a better output than all the concentration plants used before and the profit is naturally very much higher. I think that a treatment plant similar to this would suit your diamond mines."

CHAPTER XVI.

PETROGRAPHIC NOTES.

The following petrographic notes have been specially included in this book to make it more comprehensive. Though up till now no clue has been found regarding the exact origin of the Panna diamonds it is likely that a close petrographic study of the basic dykes of Bijawar age, of the Bundelkhand granite, of the Majgawan agglomeratic tuff and of the diamondiferous conglomerates might throw fresh light on that moot question.

Bundelkhand Granite.

The Bundelkhand granite consists principally of quartz, orthoclase felspar and green hornblende. The orthoclase is, as a rule, considerably altered and kaolinized. Chlorite and mica occur in the rock as alteration products of hornblende. The texture varies from fine-grained to coarse. In the porphyritic varieties the felspar crystals are more than two inches long. Besides orthoclase, oligoclase also occurs in the rock together with some microcline but in subordinate quantity. Magnetite occurs in the rock rather sparingly and is only found in association with the ferromagnesian constituents of the rock.

Quartz Reefs.

The Bundelkhand granite is pierced by long ridges of quartz reefs which mostly run in straight lines in an approximately north-east to south-west direction. They form a conspicuous feature of the landscape in the northern part of Bundelkhand. Some of these reefs are traceable for more than 30 miles. These reefs consist of quartz mostly of a greyish white colour. Some of the reefs contain, in addition, a large amount of impure serpentine.

Aravalli Rocks.

Ten miles to the west of Panna near a place known as Pathar Chauki on the road from Panna to Nowgong there is a small fringe of Aravalli rocks which underlies the Vindhyan formations and overlies the granites. These are for the most part composed of thin-bedded and highly contorted siliceous and jaspery rocks. There is another somewhat larger exposure of the Aravalli rocks near Bahargunj (Lat. 24°-43': Long. 80°-2'). A mica schist containing quartz, felspar, muscovite and tourmaline occurs in this locality. In a principal stream between Bahargunj and Dibar I came across water-worn boulders and pebbles of the Bijawar fault-breccia which must have been derived from some outcrop nearby. I could not trace this jasper breccia to its source but there is no doubt that it occurs somewhere near Bahargunj. Wilson had mapped the area near Bahargunj on his own map as Bijawar but as doubt had been expressed by some geologists who visited the place later of there being any Bijawar rocks proper in that area the two exposures near Bahargunj and Pathar Chauki were marked in the later maps of the Geological Survey of India as Aravalli. The presence of the bright red Bijawar breccia in the nullahs near Bahargunj show that Wilson must have come across the real Bijawar rocks when surveying the area near Bahargunj.

At the waterfall near Pathar Chauki there is an exposure of a very hard siliceous rock of a cherty nature which resembles more an indurated ash-bed of Bijawar age than a sandstone, which probably induced Wilson to mark this area as Bijawar. This indurated ash-like bed is underlain by the highly contorted jaspery rocks belonging to the Aravalli series mentioned above.

Bijawar Rocks.

Rocks of Bijawar age occur in Panna territory. The Bijawar series is composed of hematite beds, quartzites, ferruginous sandstones, cherty limestones and siliceous hornstones. The type area where these formations principally occur is situated to the south, the south-east and south-west of Bijawar. Besides these, the Bijawar series is noted for the occurrence in it of basic dykes, ash-beds and lava-flows. The basic dykes are particularly interesting inasmuch as they are supposed to be the original home of the diamonds found in Panna territory. Another characteristic rock occurring in the Bijawar formations is the Bijawar jasper-breccia.

Basic Dykes of Bijawar Age.

Besides the quartz reefs which traverse the granitic mass in Bundelkhand there is another set of dykes of a basic igneous rock which pierce the granite but which do not penetrate any of the younger formations. These basic dykes intersect the quartz reefs obliquely. Many of these dykes are of considerable size and attain a thickness of about 100 feet. Some of them persist for miles. It is a thing worth noting that these basic dykes are plentiful in the granite region due north of the diamond fields. West of longitude 79°-45′ their occurrence is rather restricted. Thus for instance in the granite area near Chhatarpur and Bijawar the dykes are not so numerous as in the area between longitude 80° and longitude 80°-30′. Near Ajaigarh the dykes are numerous.

I collected specimens of the dyke-rock from near Bhojbai and the hills near Ajaigarh and also from the nullah at the base of the Bisramgunj Ghat and carefully examined thin sections of the same under the petrological microscope. The specimens turned out to be granophyric augite-diorite as the following descriptions will show. The rock appears greenish in colour in hand specimens. In texture the rock varies from coarse-grained to fine-grained. I saw both the varieties at all the localities mentioned above. Under the microscope the coarse variety revealed a holocrystalline texture, the minerals composing the rock being principally plagioclase felspar and augite. There is a fair amount of quartz, many of the grains having intergrown with felspar as micropegmatite. Some of the quartz grains occur in a free state. The augite is in most cases clear and shows bright polarisation colours under the microscope; it also shows twinning. The felspar which is plagioclase is mostly turbid and altered though in some specimens I saw two distinct generations of felspars, one set having altered considerably while the other was quite clear and fresh. In some specimens the augite was found to have somewhat altered to hornblende and chlorite. In some of the specimens two distinct structures could be seen, one granophyric due to the micrographic intergrowth of quartz and felspar and the other ophitic, due to the felspars having been enclosed by large plates of augite. It may be mentioned that many of the quartz grains were found to contain needle-like inclusions. Magnetite occurs in all the specimens. The felspar was considerably altered to earthy kaolin and calcareous material. Zoning was shown by some of the felspar crystals. It will be seen from the above that the essential minerals of which the rock is composed are augite, plagioclase felspar and quartz, and as the quartz and felspar are intergrown the rock may be called granophyric augite-diorite. (Figs. 22 & 23.)

Near Bahargunj (Lat. 24°-43′, Long. 80°-3′) there is an exposure of Bijawar breccia. Water-worn boulders and pebbles of this rock occur in a principal stream between Bahargunj and Dibar. To the uninitiated the Bijawar breccia occurring in the above locality would look very much like the Panna diamondiferous conglomerate as both are much alike in appearance. The Bijawar breccia is however the brighter coloured of the two due to the greater amount of red jasper both in the matrix and in the pebbles which form the rock. The Panna conglomerate on the other hand is characterized by the presence of a green vitreous quartzite belonging to the Lower Vindhyans. A careful study of the Bijawar conglomerate revealed the presence of pebbles of the following rocks and minerals :—

Bijawar Breccia.

Bright-red jasper; dark-red hematitic jasper ; quartzite ; yellow siliceous rock ; hornstone and milky quartz. All these pebbles were set in a coarse-grained siliceous matrix. The largest pebbles were about 1½ inches long.

Majgawan Agglomeratic Basic Tuff.

The specimens examined were cores 1½″ diameter obtained from a boring put down near Inota (Lat. 24°-39′, Long. 80°-4′) and which reached a depth of 242 feet from the surface. Some of the cores were found to contain xenoliths of quartzite, red jasper, vein-quartz, sandstone, and black shales, most probably Semri shales. The xenoliths occur not only in the upper levels but were found up to a depth of 216 feet from the ground level and probably occur at still greater depths.

The colour of the tuff varies from dark greyish-green to dark greenish-grey in hand specimens. The tuff is overrun by veins and nets of calcite and dolomite. Zeolites could be seen with a lens on the surface of many of the cores. Pyrites also occur, though less frequently. Under a polarising microscope thin sections show in the majority of cases idiomorphic outlines of olivine * which has altered mostly to serpentine; in some cases the change is to spherutitic aggregations of chlorophœite. The ground-mass consists mostly of serpentinous clay with occasional patches of brownish and greenish decomposed matter. Calcite occurs plentifully in the tuff. Magnetite also occurs largely in the form of dust, granules and patches. The yellowish tuff which occurs above the greenish tuff is nothing but a more altered form of the latter resulting from the decomposition of the material forming it.

Siliceous Bands occurring in the Majgawan Tuff.

A glance at the section of the Majgawan bore-hole will show that bands of hard siliceous and calcareous material occur in it at various levels. I have selected three characteristic specimens occurring at depths of 63′-4″, 110′-0″ and 222′-2″ to show their structure and composition.

The hard siliceous band which occurs at a depth of 63′-4″ from the surface consists largely of opaline silica and brownish fragments of an ashy material. Under the microscope the structure appears distinctly brecciated, the fragments of brownish ash standing out in relief in the clear ground-mass consisting of silica (See Fig. 33). The brownish ashy substance looks very similar to a porcellanic brownish coloured rock as it would appear in a thin section under the microscope. Some of this brownish material is run over by stringers of quartz. A little calcite also occurs in this rock.

The thin band of hard rock occurring at a depth of 110′-0″, from the surface consists mostly of calcite, some

* The outlines of some of the pseudomorphs are suggestive of the presence of pyroxene also in the original rock.

greenish and yellowish green viridite, quartz and magnetite. Under the microscope the rock appears honeycombed by its being run over by rods and stringers of magnetite. The greenish viridite occurs in the form of oval and circular patches surrounded by a clear fringe of quartz. In many instances magnetite grains are symmetrically arranged around the periphery of these patches (See Fig. 36). Some parts of the slide appear quite opaque due to the presence of fine black dusty matter. Where these dust segregations are less dense the section appears of a brownish colour due probably to the peroxidation of the magnetite. Opaline silica is also present in this rock but is subordinate in amount to the calcite. The minerals which enter into the composition of this rock are therefore calcite, quartz, greenish decomposed substance, magnetite in the form of dust, grains, rods and stringers, and fine black and brownish dusty matter, some sillimanite and a lot of leucoxene.

The siliceous band occurring at a depth of 222′-2″ from the surface consists of quartz grains showing strain shadows and a radiate structure together with calcite which occurs in the shape of veins and also as grains and patches. There is plenty of magnetite in the rock which occurs mostly in the shape of irregular patches and as dust and slender rods and needles. Besides these, there is present in the rock some brownish and greenish substance which is most probably the alteration product of some ferromagnesian minerals (See Fig. 35). This rock is of a dark greyish colour.

The Diamondiferous Conglomerate.

The Panna diamondiferous conglomerate consists of pebbles and nodules of vein-quartz, red and grey jasper, aplite, hematite and limonite, green and grey quartzite together with clay galls and tablets—all firmly cemented together by a siliceous and ferruginous matrix. The vein-quartz belongs to the quartz-reefs about which mention has already been made before. The red and grey jasper pebbles as also the nodules of hematite and limonite are derived from the Bijawar beds, while the green quartzite and sandstone pebbles owe their origin to the Lower Vindhyan formations. The clay galls and tablets have been most probably derived from the Palkua shales which are of a greyish colour but which get bleached after weathering and which are occasionally intensely hard. (See Photomicrographs 26, 29 & 30).

Green Quartzite.

Of all the pebbles mentioned above, those of the green quartzite are the most interesting as according to the miners the presence of numerous pebbles and boulders of green quartzite in the diamond-bearing conglomerate almost invariably indicates a good crop of diamonds. The belief that diamonds have been known to occur inside the green quartzite is without any foundation because I have never seen the miners breaking them. The quartzite pebbles are treated as waste material and even at the present day a number of such pebbles can be seen in many of the old waste-heaps.

Under the microscope the rock is found to consist mostly of rounded and sub-angular quartz grains firmly cemented together by a siliceous matrix which is very fine grained and which therefore imparts considerable hardness and toughness to the rock. Grains of microcline and plagioclase felspars occur in this rock, though very sparingly. The contours of the individual quartz grains are very well marked owing to magnetite grains having been deposited round their periphery. The greenish colour of this rock is most probably due to some organic matter or to inclusions of green earth (delessite). During the process of slicing this rock it was observed that fairly thick, smooth, chips showed peculiar greenish yellow inclusions which, however, disappeared when the chip was ground very thin. The proportion of the siliceous matrix varies in different parts of one and the same rock. In some specimens little matrix was seen; in others, the quartz grains were closely packed together in some parts (See Figs. 24 & 27).

Sandstone immediately overlying the Diamondiferous Conglomerate; Chhaoni.

In some parts of the Shahidan diamond field, notably at Chunha, there occurs above the diamondiferous conglomerate a bed of sandstone 3 to 4 feet thick. This rock is an indurated sandstone being composed of quartz grains which are cemented together by a siliceous matrix. The quartz grains were found to contain acicular inclusions when viewed under the microscope. Besides quartz a few grains of felspar and of tourmaline were seen. The character of this rock as also the thickness of the bed composing it varies in different parts of the Shahidan field. In some parts it is only about a foot or two thick; in others the thickness is more than 4 feet. In some mines the rock is very hard and indurated, in others it is somewhat soft and shaly.

APPENDICES.

I. Copies of Reports on the Majgawan Agglomeratic Tuff.

II. A List of the Diamond Mines of Panna State.

III. Statistics of Production.

IV. Sections of Bore-holes.

V. Sections of Panna Diamond Mines as recorded by Capt. Franklin and Mon. Jacquemont.

VI. Bibliography.

VII. Locality Index.

APPENDIX I.A.

Copy of a Report on the Agglomeratic Tuff occurring at Majgawan, by W. Campbell Smith, Esq., Assistant Keeper, Mineral Department, British Museum (Natural History), London.

BRITISH MUSEUM (NATURAL HISTORY),
CROMWELL ROAD,
LONDON, S. W. 7.
MINERAL DEPARTMENT,
5*th January* 1929.

K. P. SINOR, ESQ., M.A., B.Sc.,
STATE MINING GEOLOGIST,
PANNA STATE, CENTRAL INDIA.

SIR,

I have now completed my examination of the bore-hole cores sent by you on October 29th. I am unable to add very much to your own observations which appear to be themselves fairly complete.

Sample 1 to 4, 10 and 11 are all specimens of the same kind of altered agglomerate tuff. The fragments of tuff are rich in pseudomorphs, most of which (as you suggest) appear to have been olivine. To your observations I would only add that the numerous circular patches, (sections of spherical vesicles) seen in all the fragments of tuff, recall one of the characters of palagonite-tuff. The agglomeratic tuff is certainly derived from basic olivine-rich lavas and was in all probability palagonitic. The cement of the agglomerate is partly calcitic, but spherules made up of radial groups of altered zeolites are also abundant. The substance of the pseudomorphs is difficult to determine. Its high birefringence and the positive elongation of the fibres incline one to compare it with some forms of antigorite. The double refraction is about as high as that of iddingsite. Chlorophæite is amorphous. All the chlorites have much lower birefringence than these pseudomorphs. The black fragments are, as far as I can make out, of the nature of shale, *Sample* 6 which appears to be part of a large inclusion is a very fine grained sedimentary rock, either shale, or a very fine ash. The green spots of chloritic material shown in it in thin section seem to indicate that the rock has undergone some degree of metamorphism.

Samples 5 and 8. I do not think that these differ in any essential particulars from 1 to 4, and 10 and 11. The included fragments of tuff appear to be quite the same as those in specimens 1 and 2. Some unaltered rounded grains within these tuff fragments are uniaxial and optically positive, and I can only suggest that they may be quartz picked up from sedimentary rocks.

The difference of these two samples from the others seems to be in the matrix which in part consists of some extremely fine-grained brown ashy or clayey material. The spherules of altered zeolite are rather more abundant than in the others and a few red grains may represent partly altered olivines. I do not expect metals of the platinum group would occur in these agglomerates.

As I have said above, I can add very little to what you have done yourself.

I regret that we are unable to undertake the chemical analyses for which you ask. Should you have an analysis made it would be interesting to know if it compares at all closely with any analyses of 'blue ground.'

Are these agglomerates connected in any way with the basic dikes in the Bundelkhand granite referred to by Vredenburg, as possibly representing a period of volcanic activity contemporaneous with the Bijawar system and possibly connected with the origin of the diamonds in Panna State ?

I have been interested to see these rocks, and am sorry I cannot give you any more precise replies to your questions. With much altered rocks all identifications are guesses.

Pending your instructions, I will keep all the specimens here.

Yours truly,

(Sd.) W. CAMPBELL SMITH,

Assistant Keeper,
Mineral Department.

APPENDIX I.B.

Copy of a Report on the Majgawan Agglomeratic Tuff, by Dr. A. L. du Toit, Geologist, De Beers Consolidated Mines, Ltd., Kimberley.

23rd December 1929.

Supposed Kimberlite from India:

THE ASSISTANT GENERAL MANAGER,

DE BEERS CONSOLIDATED MINES, LIMITED.

Following on our letter of the 13th instant to Mr. K. P. Sinor, the material submitted has been carefully examined both in hand specimen and in thin section, while two complete analyses have been made by Mr. J. Parry in a report to the General Manager, dated the 19th instant.

The freshest samples of the rock disclose a bluish-grey tuff with a close superficial resemblance to certain types of " blue-ground ; " indeed, until its foreign origin was established, the cores sent were thought to have come from a particular pipe in Tanganyika, that was recently being prospected by Mr. Kingsley by means of shafts and borings. As stated by the sender, it carries inclusions of foreign rocks, mainly of a dark hard shale, though some reddish quartzite was also noted.

The thin section, however, shows the rock to differ considerably from all types of South African kimberlite. The fragments composing the bulk of the tuff show under the microscope a dense blackish groundmass, practically opaque, in which are set numerous areas of dark greenish serpentine, apparently alterations from olivine, though the former presence of some proxene is not excluded. Diopside, enstatite, ilmenite, garnet and melilite were not identifiable, but some altered brown mica was present.

Calcite occurs, mainly as a cementing material between the igneous fragments, accompanied, as shown by the analyses, by some dolomite.

While the rock is naturally highly altered through serpentinization, it can provisionally be described as a *Limburgite Tuff*. Although the analyses demonstrate a silica percentage close to that of kimberlite, there are strong divergences in the case of several of the other constituents.

For example, the magnesia is low, more like that of the melilite basalts, while there is an outstandingly high proportion of titanium oxide—6·72 per cent. The natural assumption would be to regard this to be due to ilmenite, but pannings made of the crushed rock failed to disclose any conspicuous grains of that mineral, and it has therefore to be concluded that the titanium must be present in the blackish groundmass of the limburgite. The presence of magnesium carbonate is another point of difference from kimberlite.

The Panna rock must from its structure and composition be referred to the tuffs and breccias of the ultrabasic group of igneous rocks, of which practically the only member is kimberlite. Nevertheless I consider that the petrological and chemical differences are sufficiently pronounced to prevent us from classifying the Indian material among the kimberlite proper.

This conclusion should, however, not be construed as denoting that such material could not be diamondiferous. Such could only be demonstrated by means of practical tests, suggestive being Mr. Sinor's statement "There are evidences of the tuff having been worked for diamonds years ago." Owing to the absence of data concerning the precise mode of occurrence of the tuff, its relationships to the surrounding strata, etc., I am much handicapped in reaching any opinion on the habit of the material. It might well be an interstratified bed, but the fact that the bluish rock was not bottomed at 242 feet hints rather at a pipe. The only reference that can be quoted of a comparable occurrence is the statement by McLintock that a pipe of "Blue rock very similar to the blue ground of the Kimberley Mines" is known at Wajra Karur in the Golconda region, but that it carries no diamonds.

It might be remarked that the diamonds produced in Panna State are all of detrital origin, being extracted from certain pebbly bands on several horizons within a series of rather ancient sediments. The tuff gives me the impression of a volcanic material of much younger age, possibly connected with the eruptions of the Deccan "Traps" and, if so, of late Cretaceous age and hence corresponding closely with the outbursts of the kimberlites in Africa.

(Sd.) A. L. DUTOIT,

Geologist.

APPENDIX I.C.

DE BEERS CONSOLIDATED MINES, LTD.

LABORATORY,
19*th December* 1929.

Report on Two Core Samples of Rock from Panna State, India.

Received from: Mr. A. F. Williams, General Manager—an extra sample also supplied by Dr. A. L. du Toit.
Report to: General Manager and Dr. du Toit.
Examination: Full Analysis.
Fees: Research work.
Laboratory Nos: 3510 and 3511.

The samples were marked Nos. 1 and 2, and each consisted of two solid cylindrical fragments of a greyish green colour simulating certain specimens of Kimberlite. They were easily fractured and split into circular tablets as if original material were stratified.

The specific gravity of No. 1 was 2·67
„ „ „ „ No. 2 was 2·70.

The chemical composition was as follows:—

		No. 1	No. 2.
Silica	(SiO_2)	38·16	36·96
Alumina	(Al_2O_3)	4·89	6·25
Chromic Oxide	(Cr_2O_3)	0·05	0·05
Ferric Oxide	(Fe_2O_3)	5·80	6·00
Ferrous Oxide	(FeO)	5·58	5·40
Titanium Oxide	(TiO_2)	6·85	6·85
Manganese Oxide	(MnO)	0·30	0·30
Nickel Oxide	(NiO)	0·16	0·29
Calcium Oxide	(CaO)	6·72	6·72
Magnes. Oxide	(MgO)	15·40	14·76
Potass. Oxide	(K_2O)	*Nil*	*Nil*
Sodium Oxide	(Na_2O)	*Nil*	*Nil*
Phosphorus Pentoxide	(P_2O_5)	0·51	0·75
Carbon Dioxide	(C_2O)	5·52	6·88
Water	(H_2O)	4·60	3·60
Water	(H_2O)	5·42	5·66
Sulphur as Sulphide	(S)	trace	trace
		99·96	100·47

No. 1 contains 7·30% Calcite ($CaCO_3$) and 4·37% Magnesite ($MgCO_3$)
No. 2 „ 8·75% „ „ „ 5·67% „ „

Note—The Magnesia and Titanium Oxide content of the samples, which, if the material be kimberlite, are exceptional.

(Sd.) JOHN PARRY.

APPENDIX I. D.

Copy of a Report on the Majgawan Tuff sent by Sydney J. Johnstone, Esq., Vice-Principal, Mineral Resources Department, Imperial Institute, South Kensington, London.

MINERAL SAMPLE, INDIA.

The sample which is the subject of this report was sent to the Imperial Institute for examination by Mr. K. P. Sinor, Bombay, and is referred to in his letter of May 31st, 1929.

Description of Sample.

The sample consisted of boring cores, weighing about 100 lb. They appeared to be composed of a highly decomposed basic volcanic agglomerate. Serpentine, pyrites and dolomite (or other carbonate) were the most abundant minerals, but chlorite was also present in some quantity. There were also inclusions of a rock which superficially resembled a graphitic shale.

Results of Examination.

(1) *Concentration for diamonds.*

A preliminary examination was made with about 5 lb. of the material, which was soaked in water for some hours and gently crushed. The slime and material passing a 100-mesh sieve was discarded, and the remainder dried and classified into grades, which were concentrated by panning and by the use of heavy liquids. The final concentrate, which consisted almost wholly of pyrite and sillimanite, was examined under the microscope, but no diamond was found.

A further sample, weighing 85 lb., was then concentrated in the manner described below :—

The sample was soaked in water for two days and was then carefully and gently pounded until reduced to such a size that it would pass through an 8-mesh sieve. During this process a small quantity of harder material was picked out and found to consist of rock resembling black shale, jasper and quartz. The slimes were washed away, and the residue treated on a Wilfley No. 7 table. Two lots of heads and two of middlings were obtained, the latter being re-treated. The first heads were treated with bromoform, and the heavy portion saved. The second heads were carefully examined with a lens for possible diamonds, any other interesting minerals also being picked out.

The second heads and middlings were then ground to pass a 20-mesh sieve, producing as little very fine material as possible. The portion passing a 100-mesh sieve was rejected, the remainder being treated on a James table. First and second heads were collected, and second heads were re-treated.

A very clean separation was achieved, and the concentrates obtained were treated successively with bromoform and methylene iodide, the heavy portions being saved.

The principal constituents of this heavy portion of the concentrate were pyrites, magnetite, ilmenite, sillimanite, garnet, spinel, zircon, and a carbonate of magnesium and iron.

The magnetic minerals were removed with an electromagnet, and the carbonates and sulphides with nitric acid.

The final concentrate was examined with the microscope, but no diamond was found in it.

(2) *Chemical Analysis.*

A chemical analysis of the material was desired in order that comparison might be made between it and the blue ground of Kimberley.

A representative portion was therefore analysed with the results shown below. For comparative purposes seven typical analyses of Kimberley blue ground are also tabulated.

	Borings, India.	Kimberley blue ground.*						
		1	2	3	4	5	6	7
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Silica .. .. SiO_2	37.36	46.83	38.29	32.03	30.32	38.08	36.57	35.49
Alumina .. Al_2O_3	4.49	3.71	2.66	2.90	2.74	2.46	5.09	3.42
Ferric oxide .. Fe_2O_3	3.48	3.24	5.77	6.12	4.50	24.48	13.75	6.37
Ferrous oxide .. FeO	5.11	4.35	2.93	3.40	4.09	2.59	4.68	3.02
Titanium dioxide TiO_2	5.70	1.34	2.00	1.73	1.78	*Nil.*	*Nil.*	1.65
Chromic oxide . Cr_2O_3	0.11	..	..	..	..	..	..	..

* Chemical Analyses of Igneous Rocks. H. S. Washington. U. S. Geol. Survey. Prof. Paper 99.

	Borings, India.	Kimberley blue ground.*						
		1	2	3	4	5	6	7
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Lime .. .. CaO	7.24	3.83	2.42	7.60	10.40	4.14	8.49	5.12
Magnesia .. MgO	16.47	21.33	29.46	33.43	29.60	12.88	11.85	30.98
Potash .. .. K_2O	0.50	0.70	1.03	1.34	0.75	0.84	0.64	2.61
Soda .. .. Na_2O	0.62	0.63	0.30	0.35	0.45	1.12	2.55	0.20
Sulphur .. S	0.36	..	..	..	..	..	..	..
Sulphuric anhydride .. SO_3	0.14	..	..	..	..	..	..	..
Phosphoric anhydride .. P_2O_5	1.89	0.74	1.44	1.45	1.34	0.67	0.58	0.63
Carbon dioxide CO_2	6.03	..	0.20	2.50	6.21	1.67	4.61	3.03
Manganous oxide MnO	0.17	..	..	..	..	..	..	..
Moisture at 105° C. .. .. H_2O	6.06	7.95	3.13	0.51	1.19	0.25	5.47	0.47
Combined water above 105° C. . H_2O	4.48	5.22	10.19	6.31	6.56	10.14	6.31	6.69
Carbon C	0.07	..	..	..	..	..	..	..

* Chemical Analyses of Igneous Rocks. H. S. Washington, U. S. Geol. Survey. Prof. Paper 99.

As a matter of interest, an approximate chemical analysis was made of the material resembling black shales, but which appears to consist largely of quartz. The results were as follows:—

		Per cent.
Silica	SiO_2	70·0
Alumina	Al_2O_3	9·0
* Ferric oxide	Fe_2O_3	6·5
Titanium dioxide	TiO	0·5
Lime	CaO	1·5
Magnesia	MgO	5·5
Loss on ignition		4·0

* Including any iron present as ferrous oxide, FeO.

It will be seen from a consideration of the previous table that there is some general resemblance between the chemical composition of the Indian material and that of the Kimberley blue ground.

The percentage of magnesia, however, is in general much higher in the latter material, except in Nos. 5 and 6, in which there is a correspondingly higher percentage of ferric oxide. The percentage of titanium dioxide in the Indian material is distinctly higher than in the kimberlites.

It may be pointed out, however, that while rock specimens may approximate very closely in chemical composition, they are often very different from a mineralogical point of view, and a better idea of the possible similarity of the Indian borings to the Kimberley blue ground would be obtained from a consideration of their relative mineralogical compositions.

According to P. A. Wagner (The Diamond Fields of Southern Africa, 1914, p. 78), there are two varieties of kimberlite. In the first type olivine is usually found, in large and small individuals, with occasional phenocrysts of phlogopite, and isolated grains of ilmenite, enstatite, pyrope and diopside, embedded in a ground mass of secondary minerals, rich in perouskite, apatite, chromite, and iron ores. Olivine generally forms from 50 to 75 per cent. of the rock. In kimberlite of the second type one finds the same porphyritic elements as before, in a holocrystalline ground mass, of which phlogopite is the dominant constituent, and may form as much as 50 per cent. of the rock. The ground-mass minerals comprise phlogopite, olivine, apatite, perouskite, chromite and iron ores, while augite may or may not be present.

It will be seen that the mineralogical composition of kimberlite appears to differ from that of the present sample.

10th February, 1930.

APPENDIX II.

LIST OF THE DIAMOND MINES OF PANNA STATE.

For the sake of convenience the diamond mines of Panna State may be classified in seven groups as follows :—

1. Panna group of mines.
2. Shahidan mines.
3. Ranj river group of mines.
4. Korar mines.
5. Baghen river group.
6. Majgawan mines.
7. Mines in the Upper Rewa sandstone formation.

1. Panna group of mines :—

Name of mines.	Nature of workings.	Whether actively worked at present or not.
Bhawanipur	Detrital	Partially active.
Ranipur	Detrital & alluvial ..	Active.
Niranpur	Detrital	Active.
Bhaironpur	Alluvial	Occasionally worked.

2. Shahidan group of mines :—

Name of mines.	Nature of workings.	Whether actively worked at present or not.
Shahidan	Direct workings in the conglomerate.	Active.
Chunha	,, ,,	,,
Ogra	Direct and detrital ..	Occasionally worked.
Karra	Direct	,,
Pukhri	Direct and detrital ..	Closed.
Shrinagar	,, ,, ..	,,

3. Ranj river group of mines :—

Name of mines.	Character of workings.	Whether active or otherwise.
Kalianpur	Direct and alluvial ..	Closed down.
Radhapur	Alluvial	,,
Ganeshpur	,, ...	,,

4. Korar mines :—

Name of mines.	Character of workings.	Whether active or closed.
Korar	Gravel workings (shallow.)	All these mines stopped working years ago.
Bardhai	,,	,,
Kishorepur	,,	,,
Bahadurpur	,,	,,
Shikarpur	,,	,,

5. Baghen river group of mines :—

Name of mines.	Nature of workings.	Whether active at present or otherwise.
Bijepur	Direct	Recently opened.
Itwa	Direct and deep alluvial.	Active since 1919.
Barghari	Direct	Recently opened.
Birjpur	,, ...	Closed.
Maharajpur	Alluvial (deep) ..	Recently opened.
Sirswahee	,, ..	,, ,,
Bhimpahar	,, ..	Closed.
Gehra	,, ..	,,
Maira	,, ..	,,

6. Majgawan group of mines:—

Name of mines.	Nature of workings.	Whether active or not.
Maraia	Gravel workings (shallow.)	Not active since many years.
Manour	,,	
Darera	,,	
Bandi	,,	
Majgawan	Workings in agglomeratic tuff.	

7. Group of mines in the Upper Rewa newer conglomerate.

Name of mines.	Nature of workings.	Whether active or not.
Udesna	Alluvial (deep) ..	All the mines were closed many years ago. None of them is working at present with the exception of the Udesna mines which were thrown open to the public last year.
Urdana	Gravel workings (shallow.)	
Karwani	,, ..	
Durgapur	,, ..	
Gazipur	,, ..	
Nibasta	,, ..	
Matain	,, ..	
Tindini	,, ..	
Mohra	,, ..	

(REMARKS:—Unimportant "Chilla" workings have not been mentioned in the above list.)

Dalrymple's list of the old diamond mines of Panna.

A list of the old diamond mines of Panna State is given in Dalrymple's Indian Repertory. The hilly tract in which diamond mining was carried on was then called by the natives Bund Achil; this tract according to the Repertory extended about 12 coss in length and about 2 or 3 in breadth. There were 21 diamond-mining districts of which nineteen names are given :—

Name of the diamond-mining district as given in Dalrymple's Repertory.	Modern equivalent of the old name.
Pirnah	Panna.
Gurriah	Ogra.
Channu	Chunha.
Birdu	Bardhai.
Kalianpur	Kallianpur.
Etawa	Itwa.
Maharajpur	Maharajpur
Kimmerah	Khameriya.
Merah	Maira.
Singupurah	Singpur.
Mujiguah	Majgawan.
Ranpur	Ranipur.

The following seven names of diamond-mining districts as given in the Repertory cannot be identified with any of the present-day-names of villages or diamond mines :—

Anwant Pokennu.
Pullu.
Raipur.
Rajpur.
Gadasiah.
Cherriapuri.
Attupurah.

Of all the districts mentioned above those of Maharajpur, Rajpur, Kimmerah and Gadasiah were supposed to be the largest and the best.

APPENDIX III.

STATISTICS OF PRODUCTION.

TABLE I.

Statement showing the output of the Panna group of Diamond Mines from Samvat 1973 *to* 1983, i.e., *from A.D.* 1916 *to* 1927 :—

Name of Mine.	Diamonds under 1 Rati.			Diamonds above 1 Rati.			All Diamonds produced.			Royalty realized by Panna Durbar.
	No. of Dia-monds.	Weight of Diamonds.	Value realized.	No. of Dia-monds.	Weight of Diamonds.	Value realized.	Total No. of Dia-monds.	Total weight of Diamonds.	Total value realized.	
		Rati. Besi.	Rs. a. p.		Rati. Besi.	Rs. a. p.		Rati. Besi.	Rs. a. p.	Rs. a. p.
Shrinagar	44	19 2	809 12 9	41	70 12	6,836 13 0	85	89 14	7,646 9 9	1,836 3 9
Bhowanipur	100	49 0	2,243 14 9	125	245 3	30,804 15 9	225	294 3	33,048 14 6	8,263 7 6
Shahidan	1,161	617 2	36,191 10 0	831	1,552 5	2,66,703 0 6	1,992	2,169 7	3,02,894 10 6	75,201 9 6
Ranipur	5	3 7	122 15 3	17	32 13	2,184 2 6	22	36 0	2,307 1 9	557 11 9
Niranpur	45	21 19	967 15 9	29	49 10	5,162 8 0	74	71 11	6,130 7 9	1,416 15 3
Ganeshpur	2	0 3	2 2 3	..	..	....	2	0 3	2 2 3	0 8 0
Total ..	1,357	710 13	40,338 6 9	1,043	1,950 5	3,11,691 7 9	2,400	2,660 18	3,52,029 14 6	87,276 7 9

REMARKS :—In 1916, only the Shrinagar and Bhowanipur Mines were worked. At the other places working commenced since 1917. At Ganeshpur only two or three small and shallow pits were sunk in Samvat 1983, *i.e.*, in A.D. 1926.

TABLE 2.

Statement showing the output of Diamonds from the Itwa group of Mines in Panna State from April 1919 to June 1928 :—

Period.	Diamonds under 1 Rati.			Diamonds above 1 Rati.			All Diamonds produced.			Royalty realized by Panna Durbar.
	No. of Diamonds.	Weight of Diamonds.	Value realized.	No. of Diamonds.	Weight of Diamonds.	Value realized.	Total No. of Diamonds.	Total weight of Diamonds.	Total value realized.	
		Rati. Besi.	Rs. a. p.		Rati. Besi.	Rs. a. p.		Rati. Besi.	Rs. a. p.	Rs. a. p.
April 1919 to Oct. 1919 ..	351	133 17	6,183 14 6	82	124 12	16,510 4 0	433	258 14	22,694 1 6	5,801 13 9
Nov. 1921 to June 1922 ..	108	35 12	1,878 7 3	19	29 18	4,125 1 3	127	65 10	6,003 8 9	1,479 8 9
July 1922 to June 1923 ..	240	87 12	3,940 7 3	55	94 0	11,131 0 3	295	181 12	15,071 7 9	3,710 6 6
July 1923 to June 1924 ..	123	42 19	1,883 8 0	34	57 14	6,383 9 3	157	100 8	8,267 1 3	2,055 10 0
July 1924 to June 1925 ..	135	46 2	1,846 4 0	39	72 16	10,758 14 9	174	118 18	12,605 2 9	3,137 3 3
July 1925 to June 1926 ..	170	53 19	1,821 11 3	40	73 12	5,875 13 6	210	127 11	7,697 8 9	1,663 6 3
July 1926 to June 1927 ..	101	40 0	1,442 6 9	36	59 6	6,218 14 6	137	99 6	7,661 5 3	1,655 10 3
July 1927 to June 1928 ..	..	.. ..	....	..	.. ..	....	729	402 12	26,393 8 6	6,089 15 6
Total ..	..	..	....	..	..	....	2,262	1,354 12	1,06,393 12 6	25,593 10 3

REMARKS :—For two years, *i.e.*, from November 1919 up to October 1921 the Mines were not worked.

TABLE 3.

Statement showing the output of the Shahidan Diamond Mines from July 1917 to June 1927 :—

Period.	Diamonds under 1 Rati.			Diamonds above 1 Rati.			All Diamonds produced.			
	No. of Diamonds.	Weight of Diamonds.	Value realized.	No. of Diamonds.	Weight of Diamonds.	Value realized.	Total No. of Diamonds.	Total weight of Diamonds.	Total value realized.	Royalty realized by Panna Durbar.
		Rati Besi.	Rs. a. p.		Rati Besi.	Rs. a. p.		Rati Besi.	Rs. a. p.	Rs. a. p.
July 1917 to June 1918 ..	11	5 13	249 12 9	17	31 13	4,252 11 0	28	37 6	4,502 5 6	1,040 15 6
July 1918 to June 1919 ..	481	264 8	15,387 11 3	327	614 16	1,20,402 15 6	808	879 4	1,35,790 11 9	35,613 13 3
July 1919 to June 1920 ..	141	74 8	4,427 15 0	118	200 8	36,233 9 9	259	274 16	40,661 8 9	10,219 9 9
July 1920 to June 1921 ..	166	89 5	5,802 2 6	116	226 15	37,613 7 3	282	316 0	43,415 8 9	10,189 2 3
July 1921 to June 1922 ..	73	37 8	2,154 8 6	63	132 0	21,594 6 3	136	169 8	23,748 14 9	5,767 6 3
July 1922 to June 1923 ..	196	95 11	5,653 2 9	122	209 7	31,847 7 0	318	304 18	37,500 7 6	8,770 12 6
July 1923 to June 1924 ..	3	1 11	122 0 0	2	3 2	187 15 3	5	4 13	309 15 3	71 10 3
July 1924 to June 1925 ..	22	9 17	333 15 3	18	32 6	2,622 10 3	40	42 3	2,956 9 6	670 13 6
July 1925 to June 1926 ..	10	5 17	256 12 0	12	25 4	2,787 15 9	22	31 1	3,044 11 9	609 11 0
July 1926 to June 1927 ..	58	33 4	1,803 10 0	36	76 12	9,160 3 0	94	109 18	10,963 13 0	2,247 11 3
Total ..	1,161	617 2	36,191 10 0	831	1,552 5	2,66,702 9 6	1,992	2,169 7	3,02,894 10 6	75,201 9 6

REMARKS :—The considerable decline in the output from July 1923 to June 1926 was due not to the falling off in the grade of the diamondiferous ore but because very few pits had been sunk. As some of the Mine-owners had not declared many diamonds obtained from their mines the Panna Durbar had to take severe steps against them. This caused a set back for the period mentioned. The decline in the output has been attributed by many who are not in the know to the exhausted condition of the mines. Such, however, is by no means the case.

TABLE 4.

Statement showing the monthly output of the Itwa group of Diamond Mines from July 1927 to June 1928.—

Period.		No. of Diamonds.	Weight of Diamonds.		Value realized.			Royalty realized by Panna Durbar.			REMARKS.
			Rati.	Besi.	Rs.	a.	p.	Rs.	a.	p.	
July	1927	1	1	0	63	0	0	15	8	3	The output of the Itwa group of Mines for the period July 1927 to June 1928 has been the highest ever recorded since 1919. The writer has no knowledge of what the output for 1928-29 was. He repeatedly wrote to the Panna Durbar to supply him with the necessary figures but so far they have not been received. The reason why the output in 1927-1928 was the largest was that besides the Itwa Mines proper, new workings had been opened out at Sirswahee (Maharajpur) and at Barghari at the author's recommendation. If the figures for 1928-29 are received in time for publication they will be given in the Appendix.
August	1927	44	28	14	1,631	12	6	352	9	0	
September	1927	74	40	7	1,715	0	9	370	9	6	
October	1927	15	12	9	1,158	7	3	250	3	9	
November	1927	1	0	14	44	5	6	9	9	6	
December	1927	4	1	18	19	5	6	4	3	0	
January	1928	6	3	8	243	7	3	52	9	6	
February	1928	6	8	0	1,274	13	9	275	6	6	
March	1928	41	20	17	1,056	6	9	236	6	3	
April	1928	133	66	17	4,505	8	3	1,060	6	3	
May	1928	217	114	4	7,991	13	3	1,898	13	9	
June	1928	187	104	4	6,689	11	9	1,563	11	3	
Total for the 12 months	..	729	402	12	26,393	8	6	6,089	15	6	

TABLE 5.

Statement showing the monthly output of the Panna group of Mines from July 1927 to June 1928 :—

Period.		No. of Diamonds.	Weight of Diamonds.		Value realized.			Royalty realized by Panna Durbar.			REMARKS.
			Bati.	Besi.	Rs.	a.	p.	Rs.	a.	p.	
July	1927	19	25	7	2,887	12	0	636	14	9	The output during the period under review was considerably less due to the fact that the number of pits sunk were very few owing to the heavy rains in 1926. The maximum activity is observed in the Shahidan field after a dry year, the reason being that the conglomerate bed could be worked out easily as there would not be much trouble due to the influx of water from old adjoining pits. The output of diamonds from July 1918 to June 1919 in the Shahidan field alone was 879 ratis valued at Rs. 1,35,790. The output in any particular year naturally depends upon the number of pits sunk during that year. If the number of pits sunk are few the output is bound to be low. Figures for 1928-29 have not yet been received from the Panna Durbar though the author repeatedly requested them to do so.
August	1927	27	23	11	2,002	10	6	416	3	3	
September	1927	13	12	14	1,810	14	6	391	11	6	
October	1927	12	14	7	825	3	3	180	4	6	
November	1927	7	7	13	640	15	0	144	5	3	
December	1927	3	4	3	340	1	6	78	9	9	
January	1928	5	4	7	244	15	0	56	6	6	
February	1928	5	9	18	1,148	7	3	337	4	3	
March	1928	7	10	12	1,668	0	3	402	4	9	
April	1928	10	21	1	2,108	5	3	656	14	0	
May	1928	8	10	18	1,051	6	6	223	2	6	
June	1928	13	13	18	931	2	0	196	2	0	
	Total ..	129	158	9	15,659	13	0	3,720	3	0	

TABLE 6.

Statement showing the output of Diamonds weighing more than 6 *Ratis found in Panna and Itwa Mines from* 1917 *to* 1928:—

Year.	No. of diamonds.	Weight of diamonds.		Estimated value.			Prize money given to finders.		
		Rati.	Besi.	Rs.	a.	p.	Rs.	a.	p.
1918	2	21	14	3,128	0	0	531	13	3
1919	11	111	2	22,816	0	0	5,068	12	3
1920	5	43	5	8,318	0	0	654	3	9
1921	1	14	11	5,456	0	0	927	9	0
1922	..	..		..			..		
1923	3	20	15	2,985	0	0	507	7	3
1924	2	18	16	2,835	0	0	481	15	3
1925	1	6	4	1,240	0	0	210	12	10
1926	..	..		..			..		
1927	1	13	12	748	0	0	127	2	7
1928	1	20	2	3,517	0	0	587	15	6
Total ..	27	270	1	51,044	0	0	9,097	11	8

TABLE 7.

Statements showing the number of stray diamonds picked up from the ground in the diamond-fields from 1918 *to* 1928:—

Year.	No. of diamonds.	Weight of diamonds.		Estimated value.			Prize money given to finders.		
		Rati.	Besi.	Rs.	a.	p.	Rs.	a.	p.
1918	1	1	5	112	8	0	19	2	0
1919	5	4	1	544	8	0	92	8	9
1920	..	..		..			..		
1921	..	..		..			..		
1922	3	4	2	609	0	0	103	8	7
1923	5	8	1	1,666	8	0	283	5	0
1924	..	..		..			..		
1925	2	2	3	232	0	0	54	4	0
1926	3	4	5	687	0	0	171	12	0
1927	2	1	1	24	4	0	6	1	0
1928	..	..		..			..		
Total ..	21	24	18	3,875	12	0	730	9	4

Stray diamonds picked up from the ground are known as "Dare" diamonds in Hindi. Such diamonds are considered to be the property of the Durbar, the finder only having a claim to the prize-money.

TABLE 8.

Production of Diamonds in Panna State from the 1st July 1928 to 30th June 1929.

Name of Mine.	No. of Diamonds.	Weight of Diamonds.		Value realized.			Royalty received by the Durbar.			REMARKS.
		Rati	Besi.	Rs.	a.	p.	Rs.	a.	p.	
Shahidan	253	358	12	40,105	9	6	8,758	5	0	The output of the Shahidan Diamond Mines shows an increase over that of previous years except 1918-19. This is a very significant fact. The beneficial effects of the installation of rock-crusher, washing pan and jig will be more pronounced after two or three years provided there is proper supervision. While the output from the Bhawanipur mines has fallen that from the adjoining Ranipur mines has increased considerably.
Niranpur	94	105	16	8,890	10	9	2,186	8	0	
Ranipur	21	32	14	4,549	1	3	1,105	13	9	
Bhawanipur	4	4	2	261	6	3	59	7	0	
Radhapur	5	1	0	32	8	9	6	8	0	
Itwa (Pati)	133	79	12	5,796	8	6	1,252	2	9	The production from the Itwa group of mines during the period under review was satisfactory though the output has declined somewhat from Rs. 26,393 to Rs. 22,518.
Barghari	195	108	17	7,475	3	6	1,614	13	0	
Maharajpur (near Sirswahee) ..	213	124	18	8,708	5	3	1,881	4	0	
Bijepur	5	4	18	538	13	0	116	6	9	
Udesna (Maharajpur)	34	17	0	1,328	14	6	265	12	9	If more men could be induced to work the Udesna alluvial mines the output there would increase considerably as in my opinion there would still be several areas in the gorge where rich pay-chutes well worth working would be found.
" Daré " diamonds found lying on the ground	65	27	4	1,894	4	6	467	1	0	
Total ..	1,022	864	13	79,581	5	9	17,714	4	0	

TABLE 9.

Statement showing the Out-put of Diamonds in Panna State from 1st July 1929 to 31st December 1929.

Name of Mine.	No. of Diamonds.	Weight of Diamonds.		Value.		
		Rati	Besi.	Rs.	a.	p.
Shahidan	625	618	7	42,087	2	0
Niranpur	28	40	1	2,463	15	0
Ranipur	54	75	1	7,929	2	0
Sakeria	3	1	7	18	6	3
Itwa (Pati)	208	111	13	7,353	12	9
Barghari	85	40	0	1,416	13	0
Maharajpur (Itwa) ..	71	46	9	3,450	7	6
Gravel workings in the bed of the Baghen river..	14	5	8	155	14	3
		Rati	Besi.	Rs.	a.	p.
Total ..	1,088	938	6	64,875	8	9

NOTE :—The above statement was received just in time for inclusion in this book.

APPENDIX IV.

Borehole Sections.

SECTION OF SHAHIDAN BORE-HOLE, NO. 1.

Nature of formation.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Surface soil	6	0	6	0
Pebbles	0	6	6	6
Green shale	3	6	10	0
Hard quartzitic rock	1	0	11	0
Green shale	7	0	18	0
Sandstone	1	6	19	6
Shale	1	0	20	6
Sandstone	0	6	21	0
Shale	2	6	23	6
Hard quartzitic rock	0	8	24	2
Fine-grained diamondiferous conglomerate ..	0	5	24	7
Chocolate-coloured diamondiferous conglomerate	0	3	24	10
Hard sandstone	4	2	29	0
Sandstone, ordinary	4	6	33	6
White sandstone	2	8	36	2
Reddish-brown sandstone	0	2	36	4
White sandstone	1	8	38	0
Sandstone, ordinary	5	0	43	0
Hard white sandstone	3	0	46	0
Reddish-brown sandstone	0	2	46	2
Buff-coloured sandstone	1	10	48	0
White sandstone	10	0	58	0
Sandstone, ordinary	15	6	73	6
Soft sandstone	0	6	74	0
White sandstone	3	0	77	0
Soft sandstone	0	3	77	3
Sandstone, ordinary	6	3	83	6

SECTION OF SHAHIDAN BORE-HOLE, No. 1—*contd.*

Nature of formation.	Thickness. Ft.	Thickness. Ins.	Depth from surface. Ft.	Depth from surface. Ins.
Soft greyish sandstone	0	6	84	0
Ordinary white sandstone	9	9	93	9
Brownish soft sandstone	0	3	94	0
Ordinary sandstone	0	6	94	6
Soft sandstone, greyish	0	3	94	9
Ordinary sandstone	3	0	97	9
Soft sandstone	0	3	98	0
Ordinary sandstone	9	6	107	6
Soft sandstone	0	3	107	9
Ordinary sandstone	5	9	113	6
Brownish sandstone	0	6	114	0
White sandstone	2	0	116	0
Ordinary sandstone	1	0	117	0
Brownish sandstone	1	0	118	0
Ordinary white sandstone	6	8	124	8
Greyish sandstone	0	4	125	0
Ordinary sandstone	1	0	126	0
Brownish sandstone	2	0	128	0
Ordinary sandstone	2	0	130	0
Brownish sandstone	4	0	134	0
Hard white sandstone	37	0	171	0
Greyish sandstone	5	0	176	0
Ordinary sandstone	1	0	177	0
Grey sandstone	9	6	186	6

SECTION OF SHAHIDAN BORE-HOLE NO. 2.

Nature of formation.	Thickness. Ft.	Thickness. Ins.	Depth from surface. Ft.	Depth from surface. Ins.
Surface soil	5	0	5	0
Pebbles	2	6	7	6
Soil	2	6	10	0
Pebbles	0	6	10	6
Clay	5	6	16	0
Pebbles	0	6	16	6
Clay	3	6	20	0
Chocolate-coloured shale	19	6	39	6
Sandstone	0	6	40	0
Chocolate shale	6	0	46	0
Quartzose sandstone	0	4	46	4
Chocolate shale	5	4	51	8
Green shale	1	0	52	8
Flagstone	0	4	53	0
Quartzose sandstone	1	0	54	0
Chocolate shale	0	6	54	6
Diamondiferous conglomerate	0	8	55	2
Kaimur sandstone	13	10	69	0

SECTION OF SHAHIDAN BORE-HOLE NO. 3.

Nature of formation.	Thickness.		Total depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Surface soil	5	0	5	0
Pebbles	1	0	6	0
Chocolate shale	2	6	8	6
Green shale	1	6	10	0
Sandstone parting	0	6	10	6
Green shale	4	0	14	6
Flaggy sandstone	1	0	15	6
Green shale	4	0	19	6
Sandstone parting	0	6	20	0
Green shale	3	6	23	6
Sandstone	0	6	24	0
Shale	1	0	25	0
White sandstone (Kaimur)	6	0	31	0

SECTION OF SHAHIDAN BORE-HOLE NO. 4.

Nature of formation.	Depth.		Total thickness.	
	Ft.	Ins.	Ft.	Ins.
Surface soil..	15	0	15	0
Pebbles	0	6	15	6
Chocolate shale	1	6	17	0
Sandstone parting	0	6	17	6
Green shale	5	6	23	0
Flaggy sandstone	1	0	24	0
Green shale	8	6	32	6
Conglomerate (diamondiferous)	0	3	32	9
Sandstone (Kaimur)	5	3	38	0

SECTION OF SHAHIDAN BORE-HOLE NO. 6.

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Surface soil	1	6	1	6
Sandstone pebbles	0	6	2	0
Soil	3	6	5	6
Standstone pebbles	2	0	7	6
Soil	1	6	9	0
Chocolate-coloured shale	5	0	14	0
Flagstone	0	2	14	2
Chocolate shale	6	1	20	3
Flagstone	0	3	20	6
Shale	2	6	23	0
Sandstone	2	0	25	0
Chocolate shale	10	0	35	0
Sandstone	0	8	35	8
Shale	2	4	38	0
Sandstone	0	4	38	4
Shale	1	8	40	0
Flagstone	0	2	40	2
Shale	4	4	44	6
Flagstone	0	4	44	10
Shale	1	4	46	2
Sandstone	1	0	47	2
Shale	3	10	51	0
Flagstone	0	10	51	10
Shale	3	12	55	0
Flagstone	0	6	55	6
Diamondiferous conglomerate	0	2	55	8
Kaimur sandstone	10	10	66	6

REMARKS :—Not far from this boring and on all sides of it there are several old pits which are reputed to have yielded a good crop of diamonds and still the thickness of the conglomerate. as indicated by the above section, is only 2", which shows that the conglomerate is evidently thick in some parts and thin in others.

SECTION OF PANNA BORE-HOLE, No. 1, BETWEEN THE POWER HOUSE AND RANIBAG.

Nature of strata.	Thickness. Ft.	Thickness. Ins.	Depth from surface. Ft.	Depth from surface. Ins.
Surface soil..	2	6	2	6
Decomposed shale	7	6	10	0
Green shale	1	0	11	0
Sandstone	3	6	14	6
Green shale	3	6	18	0
Chocolate shale	3	0	21	0
Sandstone	0	6	21	6
Chocolate shale	1	6	23	0
Sandstone	0	6	23	6
Chocolate shale	1	0	24	6
Sandstone	0	3	24	9
Chocolate shale	2	3	27	0
Sandstone	2	6	29	6
Green shale	1	6	31	0
Sandstone	3	0	34	0
Chocolate shale	3	0	37	0
Sandstone	1	0	38	0
Chocolate shale	1	6	39	6
Sandstone	0	6	40	0
Chocolate shale	3	0	43	0
Sandstone	1	6	44	6
Chocolate shale	4	6	49	0
Green shale	1	0	50	0
Sandstone	0	6	50	6
Green shale	1	2	51	8
Sandstone	0	4	52	0
Green shale	1	0	53	0
Sandstone	3	6	56	6
Green shale	0	6	57	0
Sandstone	1	0	58	0
Green shale	4	0	62	0
Sandstone (Kaimur)	7	0	69	0

SECTION OF PANNA BORE-HOLE, No. 2, NEAR RANIBAG.

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Surface soil..	3	0	3	0
Sandstone	1	6	4	6
Shale	1	6	6	0
Sandstone	1	6	7	6
Shale	1	0	8	6
Flaggy sandstone	3	0	11	6
Greenish shale	2	0	13	6
Sandstone	2	0	15	6
Green shale	1	0	16	6
Sandstone	1	0	17	6
Green shale	1	6	19	0
Sandstone	1	0	20	0
Green shale	0	6	20	6
Sandstone	1	0	21	6
Green shale	0	6	22	0
Sandstone	1	0	23	0
Green shale	1	0	24	0
Sandstone	1	3	25	3
*Conglomerate (diamondiferous)	0	6	25	9
Sandstone	0	9	26	6
Green shale	2	0	28	6
Sandstone	0	6	29	0
Chocolate shale	3	6	32	6
Sandstone	1	6	34	0
Chocolate shale	2	6	36	6
Sandstone	4	0	40	6
Green shale	2	6	43	0
Sandstone	0	4	43	4
Chocolate shale	1	6	44	10
Sandstone	1	2	46	0
Chocolate shale	3	0	49	0
Sandstone	0	6	49	6

*** The position of the conglomerate, as revealed by this bore-hole, is not the usual one between the Jhiri shales and the Upper Kaimur sandstone but a higher horizon among the Jhiri shales.**

SECTION OF PANNA BORE-HOLE, No. 2, NEAR RANIBAG.—*Contd.*

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Chocolate shale	1	0	50	6
Sandstone	1	2	51	8
Chocolate shale	1	6	53	2
Sansdstone	0	10	54	0
Chocolate shale	0	6	54	6
Sandstone	0	6	55	0
Chocolate shale	2	6	57	6
Sandstone	1	0	58	6
Green shale	1	6	60	0
Chocolate shale	1	0	61	0
Green shale	1	0	62	0
Sandstone	3	0	65	0
Green shale	0	6	65	6
Sandstone	1	6	67	0
Chocolate shale	1	6	68	6
Green shale, hard)	3	2	71	8
Sandstone, (Kaimur)	9	4	81	0

SECTION OF JHARUAPUR BORE-HOLE NO. 1.

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Surface soil	3	0	3	0
Sandstone	0	6	3	6
Clay	4	6	8	0
Sandstone	1	0	9	0
Clay	1	6	10	6
Sandstone	1	0	11	6
Green shale	6	6	18	0
Sandstone	1	0	19	0
Green shale	6	0	25	0
Sandstone	2	0	27	0
Green shale	1	0	28	0
Chocolate shale	3	0	31	0
Sandstone	0	6	31	6
Chocolate shale	1	0	32	6
Sandstone	1	6	34	0
Chocolate shale	2	0	36	0

This bore-hole was stopped when it attained a depth of 36 feet as it kept caving badly.

JHARUAPUR BORE-HOLE NO. 2.

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Surface soil	2	0	2	0
Gravel	2	6	4	6
Sandstone	1	0	5	6
Clay	2	0	7	6
Sandstone	1	6	9	0
Clay	1	0	10	0
Sandstone	1	0	11	0
Shale	2	0	13	0
Sandstone	0	6	13	6
Shale	6	0	19	6
Sandstone	1	0	20	6
Shale	3	0	23	6
Sandstone	1	0	24	6
Chocolate shale	2	6	27	0
Green shale	3	0	30	0
Sandstone	1	6	31	6
Green shale	2	0	33	6
Sandstone	1	6	35	0
*Diamondiferous conglomerate	0	6	35	6
Laterite	0	6	36	0
Chocolate shale	6	0	42	0
Sandstone	0	6	42	6
Brownish shale	2	0	44	6
Sandstone	0	6	45	0
Brown shale	5	0	50	0
Sandstone	4	6	54	6
Green shale	15	6	70	0
Sandstone (Kaimur)	7	6	77	6

*The position of the diamond-bearing conglomerate is in the Jhiri shales and not below it.

SECTION OF ITWA BORE-HOLE NO. 1 PUT DOWN NEAR THE PRESENT-DAY ALLUVIAL WORKINGS IN ITWA.

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Alluvium	24	0	24	0
Kakru (Gravel)	1	2	25	2
Sandstone	0	6	25	8
Kakru	0	6	26	2
Brown sandstone	2	0	28	2
Green shale	0	6	28	8
Chocolate shale	2	10	31	6
Brown sandstone	0	10	32	4
Chocolate shale	0	6	32	10
Green shale	1	0	33	10
Chocolate shale	1	6	34	10
Hard green shale	4	2	39	0
Kaimur sandstone	36	2	75	2

SECTION OF ITWA BORE-HOLE, No. 4 PUT DOWN NEAR THE BAGHEN RIVER.

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Surface soil	3	6	3	6
Sandstone	1	10	5	4
Yellow clay	0	8	6	0
Sandstone	2	6	8	6
Clay	0	6	9	0
Sandstone	4	6	13	6
*Conglomerate (diamondiferous)	0	6	14	0
Green shale	4	0	18	0

*The shales which occur below the conglomerate are called " Itwa shales."

SECTION OF TUBE-WELL BORE-HOLE PUT DOWN IN THE LAXMIPORE PALACE GROUND.

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Surface soil with Kankar nodules	10	0	10	0
Clay and pebbles	13	0	23	0
Green shale	16	6	39	6
Sandstone	1	0	40	6
Green shale	8	0	48	6
Sandstone	1	6	50	0
Green shale	1	6	51	6
Sandstone	1	6	53	0
Green shale	1	0	54	0
Hard and tough sandstone	3	0	57	0
Shale	2	6	59	6
Sandstone	3	0	62	6
Green shale	1	0	63	6
Sandstone	0	6	64	0
Green shale	1	6	65	6
Sandstone parting	0	6	66	0
Green shale	1	0	67	0
Sandstone parting	1	0	68	0
Green shale	1	6	69	6
Sandstone	0	6	70	0
Green shale	2	0	72	0
Sandstone	2	4	74	4
Shale	1	0	75	4
Sandstone parting	0	2	75	6
Green shale	0	6	76	0
Sandstone	1	0	77	0
Green shale	0	6	77	6
Sandstone	5	0	82	6
Shale	0	6	83	0
Shaly sandstone	1	6	84	6
Sandstone	7	6	92	0
Shaly sandstone	3	6	95	6
Hard sandstone	2	0	97	6
Shaly sandstone	1	0	98	6
Hard sandstone	1	0	99	6

SECTION OF TUBE-WELL BORE-HOLE PUT DOWN IN THE LAXMIPORE PALACE GROUND—*contd.*

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Shaly sandstone	5	6	105	0
Shale	2	0	107	0
Sandstone	2	6	109	6
Sandstone with shale bands	4	0	113	6
Hard sandstone	0	6	114	0
Shaly sandstone	1	6	115	6
Hard sandstone	7	0	122	6
Shaly sandstone	4	6	127	0
Sandstone	2	0	129	0
Diamond bearing conglomerate	0	2	129	2
Hard sandstone	1	10	131	0
Shaly sandstone	3	6	134	6
Chocolate shale	9	0	143	6
Shaly sandstone	3	6	147	0
Chocolate shale	4	0	151	0
Hard green shale	1	0	152	0
Shaly sandstone	2	0	154	0
Green shale	0	6	154	6
Kaimur sandstone..	92	0	246	6

SECTION OF TUBE-WELL BORE-HOLE, IN DEWAN BAHADUR NANHEY RAJA SAHEB'S KOTHI, PANNA.

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Surface soil	8	0	8	0
Sand and gravel	13	0	21	0
Shale	1	6	22	6
Flaggy sandstone	0	6	23	0
Shale	1	0	24	0
Sandstone	1	0	25	0
Shale	2	6	27	6
Sandstone	1	6	29	0
Green shale	3	6	32	6
Sandstone	0	6	33	0
Green shale	1	0	34	0
Sandstone	1	6	35	6
Shale	1	6	37	0
Sandstone	1	0	38	0
Shale	1	0	39	0
Sandstone	0	4	39	4
Shale	2	2	41	6
Sandstone	1	0	42	6
Shale	2	0	44	6
Sandstone	1	6	46	0
Shale	2	0	48	0
Sandstone	0	6	48	6
Shale	5	0	53	6
Sandstone	1	0	54	6
Shale	1	6	56	0
Sandstone	1	4	57	4
Shale	3	0	60	4
Sandstone	1	8	62	0
Shale	1	0	63	0
Sandstone	0	6	63	6
Shale	3	6	67	0
Sandstone	1	0	68	0
Shale	2	6	70	6
Sandstone	1	0	71	6

SECTION OF TUBE-WELL BORE-HOLE, IN DEWAN BAHADUR NANHEY RAJA SAHEB'S KOTHI, PANNA—*contd.*

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Shale	0	6	72	0
Sandstone	0	6	72	6
Chocolate shale	1	6	74	0
Sandstone	0	6	74	6
Green shale	3	6	78	0
Sandstone	3	6	81	6
Chocolate shale	0	6	82	0
Sandstone	1	6	83	6
Chocolate shale	4	6	88	0
Sandstone	1	0	89	0
Chocolate shale	0	6	89	6
Sandstone	5	0	94	6
Chocolate shale	0	6	95	0
Sandstone	3	0	98	0
Chocolate shale	2	0	100	0

SECTION OF JANAKPUR BORE-HOLE.

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Surface soil	3	0	3	0
Sandstone	1	0	4	0
Siliceous shale	1	8	5	8
Ordinary shale	0	4	6	0
Sandstone	2	0	8	0
Shale	0	4	8	4
Siliceous shale	0	8	9	0
Clayey layer	1	0	12	4
Sandstone	0	6	12	10
Brown sandstone	0	2	13	0
Hard quartzitic sandstone	1	4	14	4
Shale	0	6	14	10
Sandstone	1	6	16	4
Quartzitic sandstone	0	2	16	6
Siliceous shale	1	6	18	0
Soft clayey material	3	0	21	0
Sandstone	0	6	21	6
Clayey stuff	3	6	25	0
Sandstone	0	3	25	3
Shale	1	6	26	9
Sandstone	0	3	27	0
Shale	0	9	27	9
Sandstone	0	6	28	3
Chocolate coloured shale	4	0	32	3
Sandstone	1	0	33	3
Siliceous shale	2	9	36	0
Chocolate shale	5	0	41	0
Quartzitic sandstone	0	6	41	6
Chocolate coloured shale	9	8	51	2
Quartzitic sandstone	0	2	51	4
Shale	4	10	56	2
Hard quartzitic sandstone	0	3	56	5
Shale	3	3	59	8
Sandstone	2	0	61	8
Shale	0	6	62	2
Sandstone	1	2	63	4

SECTION OF JANAKPUR BORE-HOLE—*contd.*

Nature of strata.	Thickness.		Depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Shale	8	4	71	8
Sandstone	0	6	72	2
Quartzitic sandstone	1	0	73	2
Clayey layer above conglomerate	0	6	73	8
Diamondiferous conglomerate	0	6	74	2
Sandstone	0	10	75	0
Reddish sandstone	3	8	78	8
Sandstone	1	6	80	2
Red sandstone	2	0	82	2
Hard white sandstone	26	0	108	2
Brown sandstone	3	0	111	2
Reddish sandstone	1	0	112	2
Greenish sandstone	0	6	112	8
Hard white sandstone	7	0	119	8
Red sandstone	1	0	120	8
White sandstone	8	0	128	8
Reddish sandstone	0	2	128	10
White sandstone	1	4	130	2
Yellowish sandstone	2	0	132	2
Hard white sandstone	1	0	133	2

SECTION OF TUBE-WELL BORE-HOLE PUT DOWN AT SAKARIA, 8 MILES TO THE S. E. OF PANNA IN THE UPPER REWA SANDSTONE PLATEAU.

The formations met with were Sandstones belonging to the Upper Rewa Sandstone group of the Upper Vindhyans. Though the bore-hole reached a depth of 240 feet from the ground level the jhiri shales were not encountered, the cores being of hard quartzose sandstone throughout.

APPENDIX V.

Sections of Panna Diamond Mines as given by Capt. Franklin and Jacquemount. For the sake of comparison a section of the Banaganpilly Diamond Mines recorded by Voysey is also given.

SECTION :—FRANKLIN.		SECTION :—JACQUEMONT.		SECTION :—VOYSEY.	
Panna Mines.		*Panna Mines.*		*Banaganpilly Mines.*	
Soil .. .. Red gravel	2 feet.	Soil .. .. Red gravel .. .. .. Blocks of neighbouring sandstones and portions of Red, Blue and Green shales.	0 metres to 3 metres.	Sandstone .. .. .. Clay-slate and Slaty limestone.	50 feet.
Argillaceous shales .. .. Calcareous slates .. .. Red, Blue and Green coloured sandstones (interlaminated).	12 feet.	Red, Green and Blue shales Green shales speckled lilac .. Red, Green and Blue shales. ..	3 metres to 5 metres.	PEBBLES. Puddingstone; Quartz; Hornstone; all in argillaceous-calcareous-siliceous sand. BRECCIA. Red and yellow jasper; Quartz; Chalcedony; Hornstone of various colours in quartz sand. Diamonds	2 feet.
		Fine-grained sandstone of a green colour	0 metres to 3 metres.		
PEBBLY BED. *Composition* :— White and Green quartz .. Jasper Hornstone, Lydian stone. Portions of argillaceous schists, all in white quartz sand and ferruginous Quartz Sand. Diamonds.	2 feet	PEBBLY BED. *Composition* :— Red Jasper, Lydian stone. Milk quartz. White angular fragments of green and ferruginous sandstone. Hyaline quartz. Semi-rounded portions of micaceous shale, red, white and green in adamantine quartz sand. Diamonds	0·3 metres to 1·6 metres.		
Compact sandstone ..	400 feet.				

APPENDIX VI.

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APPENDIX VII.

LOCALITY INDEX

Name of Place.	North Latitude.			Longitude.		
	°	′	″	°	′	″
Babupur	24	48	0	80	22	30
Bahargunj	24	43	0	80	2	0
Bamuka	24	39	0	80	6	30
Bandi	24	42	0	80	8	30
Barat	24	37	0	80	1	30
Bardhai	24	47	30	80	17	0
Barghari	24	48	0	80	27	30
Barour	24	40	0	80	7	0
Bhawanipur	24	43	30	80	13	30
Bhojbai	24	51	30	80	19	30
Bijepur	24	47	30	80	23	0
Birjpur	24	48	30	80	29	0
Durgapur	24	42	0	80	33	0
Gahra	24	50	0	80	30	0
Gatrupurwa	24	49	15	80	29	15
Inota	24	39	0	80	4	0

Name of Place.	North Latitude.			Longitude.		
	°	′	″	°	′	″
Itwa	24	47	0	80	25	30
Janakpur	24	44	0	80	16	30
Jaruapur	24	41	30	80	11	0
Kacha	24	39	30	80	7	30
Kalianpur	24	44	30	80	17	30
Karwani	24	44	30	80	29	30
Kherband	24	41	0	80	11	30
Kodaia	24	47	0	80	14	0
Kusmani	24	36	30	80	0	30
Laxmipore	24	44	45	80	19	30
Maharajpur (Itwa)	24	48	30	80	27	0
Maira	24	48	30	80	24	0
Majgawan	24	48	30	80	4	30
Manour	24	43	0	80	10	0
Maraia (Itwa)	24	47	30	80	25	30
Maraia (Majgawan)	24	42	0	80	8	0
Marla	24	44	0	80	3	30
Mohra	24	43	0	80	28	0
Motwa	24	41	0	80	24	0

Name of Place.	North Latitude.			Longitude.		
	°	′	″	°	′	″
Old Panna	24	43	30	80	12	0
Panna	24	43	0	80	14	0
Pipertola	24	39	0	80	0	30
Ranipur	24	43	0	80	13	0
Sakeriya	24	39	0	80	19	30
Shivrajpur	24	39	30	80	29	0
Singhpur	24	45	30	80	38	0
Sonhara	24	43	0	80	17	30
Sukuha	24	39	30	80	10	0
Tindini	24	41	0	80	25	0
Udesna	24	40	30	80	18	30
Umerjala	24	45	0	80	25	0
Umerjalo	24	40	30	80	8	0
Urdana	24	44	45	80	27	0

NOTE :—The latitudes and longitudes given above have been taken from the topographical maps of Bundelkhund on a scale of 1 inch = 1 mile, published by the Survey of India.

PHOTOMICROGRAPHS

PLATE XVII.

FIG. 22.
Basic dyke-rock of the Bijawar series. This rock consists essentially of augite, plagioclase felspar, quartz, magnetite and a little chlorite and hornblende, the two latter being alteration products of augite. The micro structure is partly granophyric and partly ophitic. Ordinary light. Magn. 30.

FIG. 23.
Another section of the Bijawar rock which is really a quartz-plagioclase-augite rock. Crossed nicols. Magn. 30.

Photomicros by K. P. Sinor.

PLATE XVIII.

FIG. 24.
Green quartzite (Kansiya). This rock occurs as large and small pebbles in the diamondiferous conglomerate. It consists of grains of quartz cemented by silica. The proportion of the siliceous matrix is more in some specimens and less in others. Ordinary light. Magn. 30.

FIG. 25.
Green vitreous quartzite as seen between crossed nicols. Magn. 25.

Photomicros by K. P. Sinor.

PLATE XIX.

FIG. 26.

Section of the fine-grained conglomerate occurring on the top of the coarse conglomerate in the Shahidan mines. The photomicrograph shows a small composite pebble in the centre surrounded by grains and pebbles of gneiss, aplite and quartzite.
Ordinary light. Magn. 42.

Photomicro by K. P. Sinor.

PLATE XX.

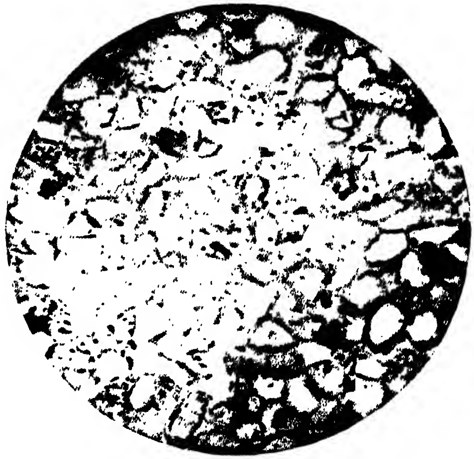


FIG. 27.
Greyish quartzite occurring in the coarse conglomerate in Shahidan mines. The illustration shows angular and sub-angular grains of quartz cemented by very fine-grained siliceous matrix. Ordinary light. Magn. 30.

FIG. 28.
The above as it appears between crossed nichols. Magn. 25.

Photomicros by K. P. Sinor.

PLATE XXI.

FIG. 29.
Fine-grained conglomerate ("Ranjika") occurring above the coarse diamondiferous conglomerate (Muddha) in the Shahidan mines. The illustration shows grains and minute pebbles of quartzite, gneiss aplite, etc. The cementing matrix is limonitic Ordinary light. Magn. 30.

FIG. 30.
Another photomicrograph of "Ranjika". The matrix here is siliceous. Ordinary light. Magn. 30.

Photomicros by K. P. Sinor

PLATE XXII.

FIG. 31.
Hard rock met with at a depth of 63 feet from the surface, in the Majgawan bore-hole. The rock is an ash breccia and is composed of fragments of a brownish ashy rock resembling porcellanite cemented by an unusually large amount of silica. Ordinary light. Magn. 30.

FIG. 32.
Section of Majgawan ash-breccia as seen between crossed nicols. The quartz grains which occur in between the fragments of the brownish ash are seen clearly in the photomicrograph. Magn. 25.

Photomicros by K. P. Sinor.

PLATE XXIII.

FIG. 33.
Another photomicrograph of ash-breccia occurring at Majgawan in the tuff. The clear parts represent quartz and a little calcite. The dark fragments are those of an ash-like substance which appear brownish in thin sections. Ordinary light. Magn. 30.

FIG. 34.
Hard siliceous band occurring in the agglomeratic tuff at Majgawan. The dark patch in the centre of the photomicrograph which has a fringe of clear quartz grains surrounding it is that of green chloritic matter. The rock contains in addition quartz, calcite, magnetite, and a fair amount of leucoxene. Ordinary light. Magn. 30.

Photomicros by K. P. Sinor.

PLATE XXIV.

FIG. 35.

Hard siliceous band occurring in the Majgawan tuff at a depth of 222 feet from the surface. The rock consists mostly of quartz, some calcite and a large quantity of greenish matter which is the result of alteration of some original ferromagnesian rock. There is abundant magnetite in this rock as seen in other sections. The dark substance seen in the figure is not magnetite but a dark greenish product allied to chlorite and viridite. Acicular inclusions of sillimanite occur in this rock as also quite a lot of leucoxene. Ordinary light. Magn. 42.

Photomicro by K. P. Sinor.

PLATE XXV.

FIG. 36.

Hard siliceous rock occurring in the Majgawan agglomeratic tuff. This rock consists essentially of grains and irregular crystals of quartz and calcite, and round and oval patches of greenish and yellowish-green chloritic material which is the result of alteration of some original ferromagnesian mineral in the rock. The rock also contains a large amount of iron oxide, and some leucoxene. The greenish patches are usually surrounded by a fringe of clear quartz grains. Ordinary light. Magn. 42.

FIG. 37.

Another photomicrograph of the hard siliceous rock occurring in the Majgawan basic tuff. The clear patches are those of quartz and calcite. The greenish patches are surrounded by a fringe of clear quartz. Iron oxide occurs plentifully in this rock in the form of dust, grains, rods and irregular patches. Ordinary light. Magn. 42.

Photomicros by K. P. Sinor.

PLATE XXVI.

FIG. 38.
Basic agglomeratic tuff occurring at Majgawan. The photomicrograph shows the opaque matrix of serpentinous clay in which are embedded serpentine pseudomorphs after olivine and a few grains and crystals of calcite. Veinlets of zeolites and calcite occur in this rock.
Ordinary light. Magn. 30.

FIG. 39.
Serpentine pseudomorph after olivine occurring in agglomeratic tuff, Majgawan.
Crossed nicols. Magn. 140.

Photomicros by K. P. Sinor.

PLATE XXVII.

FIG. 40.
Striæ and etch figures seen on the octahedroid face of a Panna diamond. Magn. 30.

FIG. 41
Another photomicrograph showing a number of etch-figures and some striæ on the octahedroid face of a Panna diamond. Magn. 30.

Photomicros by K. P. Sinor.

Plate XXVIII.

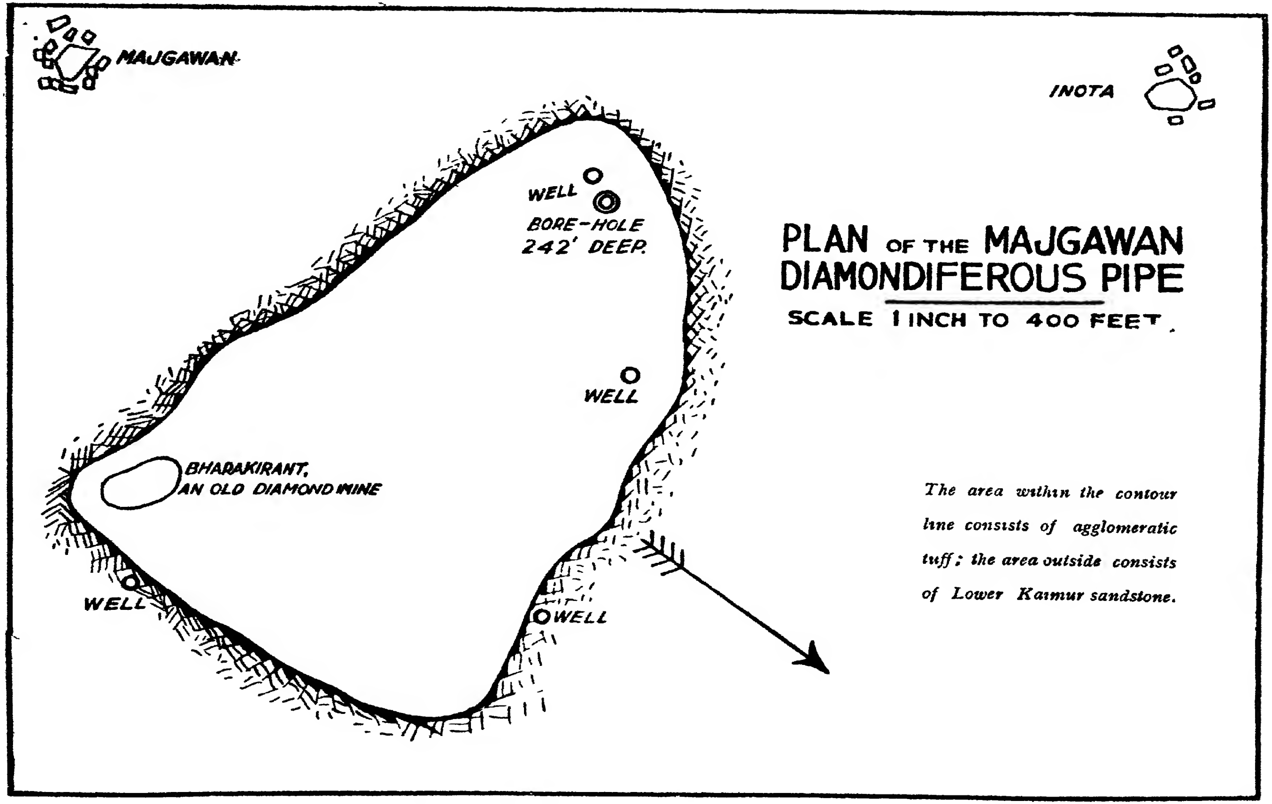
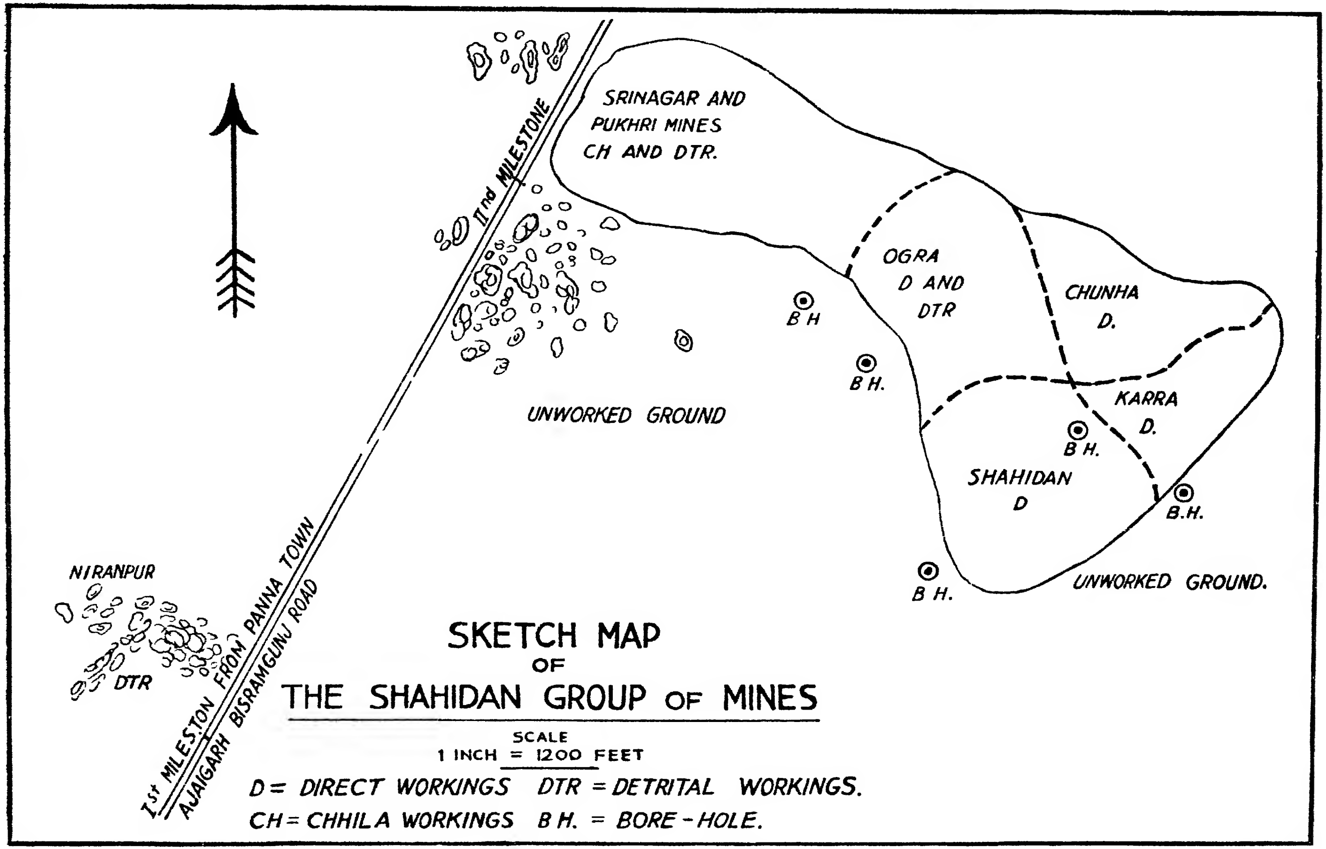


Fig. 42.


SRINAGAR AND
PUKHRI MINES
CH AND DTR.
II nd MILESTONE
OGRA
D AND
DTR
CHUNHA
D.
KARRA
D.
SHAHIDAN
D
B H
B H.
B H.
B.H.
B H.
UNWORKED GROUND
UNWORKED GROUND.
NIRANPUR
DTR
I st MILESTON FROM PANNA TOWN
AJAIGARH BISRAMGUNJ ROAD
SKETCH MAP
OF
THE SHAHIDAN GROUP OF MINES
SCALE
1 INCH = 1200 FEET
D= DIRECT WORKINGS DTR = DETRITAL WORKINGS.
CH= CHHILA WORKINGS B H. = BORE-HOLE.