Geology. — *"On the Rate of Denudation in Java"*. By Dr. L. RUTTEN. (Communicated by Prof. Dr. C. E. A. WICHMANN.)

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The present investigation is based on the tables of annual content of silt and of the annual estimates of the discharge of a number of rivers in Java, besides on occasional estimates of the solid material dissolved in their water.

It was the interesting thesis of Dr. L. G. DEN BERGER [1]) that first called my attention to the regular observations of some rivers in Java and Madura in point of their discharge, the amount of dissolved materials and their silt-content. On being asked for further information Mr. DEN BERGER kindly sent me the silt- and discharge-estimates for some typical rivers in Java, which valuable collection was afterwards supplemented by Mr. WEBER, chemist at the agro-geological Laboratorium of the Department for Agriculture. I also received valuable information from Dr. E. C. J. MOHR, Director of this Laboratory. Some modern literature was afforded me by Dr. B. G. ESCHER of Weltevreden. To these gentlemen I wish to express my warm thanks for their assistance.

With a view to difficulties of irrigation in the Seraju-system and in connection with newly projected irrigation-works Mr. MOHR had, in the year 1907, samples of water collected at regular intervals in several places in this system, which were examined at Buitenzorg. He had moreover estimates made of the discharges of these several rivers. The results of this investigation [2]), important from an agricultural point of view, prompted geologists to make similar observations also for other projected irrigation works, which were worked out later on especially by Mr. DEN BERGER and Mr. WEBER, and the practical use of which appears unequivocally from the thesis just alluded to. The values found were not only important for the agriculturist whom they taught what he brought on the fields to be irrigated, quantitatively and qualitatively, but also for the geologist,

[1]) L. G. DEN BERGER. Landbouwscheikundige onderzoekingen omtrent de irrigatie op Java. Delft. 1915.

[2]) E. C. J. MOHR. Over het slibbezwaar van eenige rivieren in het Serajoedal enz. Mededeelingen, uitgegeven door het Dept. van Landbouw, n⁰. 5. Batavia 1908.

as they bear witness to the powerful denuding agents at work in demolishing the mountains in this tropical island and illustrate how far the rate of denudation depends on the geological condition. Since, to my knowledge, the Indian geological literature does not contain anything about these problems, I entered upon a study of the available data in December last; the results have been brought together in the accompanying table and will be discussed in detail below.

The available data were:

1. Silt-contents, denoting the amount of matter held in suspension in the river water, estimated twice a day during a whole year. A few times a month simultaneous estimates were made of the silt content of the surface water and the bottomwater.

2. Discharge-estimates, corresponding with the preceding data, indicating the amount of water, in cubic meters per second, carried past the point of observation.

3. Content of dissolved solid material in the riverwater, estimated mostly only once every two months or less often.

A combination of the data 1 and 2 shows the amount of silt per second, day, month and year carried past the place of observation; that of 2 and 3 shows the amount of dissolved solid material, transported from the riversystem per month and per annum, so that apart from the material transferred to the sea along the bottom, we get in this way a survey of all the materials carried away from the riversystem in one year. Most of the observations being made in the lower course, where no doubt the bulk of the transported material in suspension and in solution are discharged, we may assume that the values found in this way, cannot be far below the real amount of the transported matter.

The total amount of the materials carried past the place of observation — by weight — was reduced to cubic meters by dividing by 2.5 — which was taken for the average specific gravity of the transported stones — and then the average annual denudation was computed by apportioning the result over the system above the place of observation.

For some rivers the observations were not made for a whole year. In those cases we made interpolations.

In view of the available material it is not pretended that these results are strictly accurate. Observations only twice a day, interpolations for some months, observations of the dissolved materials only some times a year, the absence of data of the material transported along the riverbottom, they are all factors that bring down the accuracy of the figures. On the other hand the material need not be so accurate, since the essential factor is not the extent of denudation — perhaps not even when only approximated to some tens of per cents — but only the order of this number.

In a way a rough control of the data was rendered possible. The total quantity of water carried yearly past the place of observation must of necessity be considerably smaller than the total amount of rain descended upon the river system, which represents the product of the area of the system and the mean annual rainfall. This is easy to understand if we consider that one part of the supplies of rain is removed by evaporation, another sinks into the ground, while again another portion is absorbed by the vegetation in the system. In the following pages we shall examine how far the data could stand the test of our control.

At first I made minute calculations with all the available data, but before long I deemed a rough operation of endless multiplications and additions quite sufficient. It is out of place here to reproduce the very comprehensive tables, thus obtained; I hope to make known the results of further inquiries in this direction in a future communication. The most important data of the several systems have been worked out in the said table; I subjoin some special remarks about them.

From the Tjiliwong, which drains the northern slopes of the Gedeh-Pangrango massif, nearly all the water is carried off through a large irrigation channel, the East-Slokkan, near Katu Lampa, some kilometers above Buitenzorg. So, though not the whole volume of water — consequently not all the silt — that is carried past Katu Lampa, is taken into account, the difference will be only very small, as the total annual volume of water passing through the Slokkan ($2,6\ 10^8$ m^3) is not in an abnormal ratio to the total annual rainfall in the system above the place of observation ($5.2\ 10^8$ m^3).

The Tjiliwong derives nearly all its water from a volcanic country, mostly from young volcanic breccia, tuffs and agglomerates of the Gedeh Pangrango, for a smaller portion from the so-called old-andesite massif of the G. Kentjana, G. Paseban and others, for a very small portion from the so-called miocene breccia, east of Buitenzorg[1]. The rocks in the region of the "Old Andesites" are petrographically not distinguishable from those of the Gedeh-Pangrango massif; the part of the miocene breccia, drained by the Tjiliwong

[1]) R. VERBEEK and R. FENNEMA. Geologie van Java en Madoera. 1896.

is the most recent portion of the folded, sedimentary Tertiary east of Buitenzorg and is composed entirely of andesitic sandstones and tuff-breccia.

The Tjilamaja, rising on the northern slopes of the Tangkuban Prahu massif, drains, according to VERBEEK and FENNEMA's map [1]) a region of recent volcanic rocks, of old-miocene breccia, miocene marls and quaternary I have no personal knowledge of the system, but here I feel urged to point to an error on a map in the archives of the "Dutch Colonial Petroleum Company", on which a considerable portion of the so-called miocene breccia are indicated as marls, shales and sandstones, an error quite similar to those regarding the country east of Buitenzorg [2]). This requires qualification, as it appears that in the Tjilamaja system marls and volcanic rocks in reality counterbalance each other, whereas according to VERBEEK and FENNEMA's map the volcanic rocks (*ml* and *v*) by far exceed the marly rocks.

For this river the obtained denudation value is somewhat exaggerated as the volume of water ($5{,}6\ 10^8\ m^3$) carried past the place of observation is too near the value of the total annual rainfall in the system above the place of observation ($6{,}8\ 10^8\ m^3$). Anyhow in the system of the Tjimanuk young volcanic rocks prevail. In its northern career the river also drains a small tract of miocene marls, it not being excluded that in the large tract of "miocene breccia", southwest of the G. Tjerimai, there still occur marls in a rather considerable quantity.

With regard to the Tjimanuk the obtained annual denudation is most likely an understatement, as the volume of water (2—$3\ 10^9\ m^3$) passing the place of observation is too small a portion of the total rainfall in the system (9—$10\ 10^9\ m^3$). True, in this extensive system with so many sawahs the water evaporates on a large scale, but the obtained ratio seems to be too low an estimate of the remaining flow of rainwater.

In the Kali Tandjum system young volcanic rocks, miocene breccia and miocene marls occur above Tipar, the place of observation. On VERBEEK and FENNEMA's map, however, the volcanic rocks (*ml* and *v*) far preponderate over the clayey marly rocks.

The Kali Seraju system is one of the most "mingled" systems of all Java, as it includes beside large tracts of marls, miocene breccia and recent volcanic rocks, also eocene and cretaceous rocks. The Djragung and the Pengaron derive part of their water from

[1]) See note 1 foregoing page.

[2]) L. RUTTEN. "Old Andesites" and "Brecciated Miocene" east of Buitenzorg. Proceed. of the Royal Acad. Vol. XX. Amsterdam 1918, p. 597—608.

the greatly plicated zone of miocene marls of Central Java, another part from the deposits of the Ungaran, overlying the marls. In the Kali Pengaron system marls largely predominate, which is not so much the case in the Djragung system.

Most likely the obtained denudation value is somewhat too low for the Djragung. The quantity of water, streaming past the place of observation (0,8—1, 10^8 m^3) is in a somewhat abnormal ratio to the rainfall in the system (2,6 10^8 m^3).

We do not encounter exclusively miocene limestones and quaternary in the Kali Lusi system, as indicated on VERBEEK and FENNEMA's map. According to maps in the Archives of the Dutch Colonial Petroleum Company, its southern affluents drain almost exclusively a region of soft marls and other allied rocks; its northern affluents, however, one where chiefly limestones abound. Quaternary occurs especially in the large Blora plain. I am not acquainted with this system. The extensive Brantas system is chiefly built up of volcanic rocks. Occasionally these are also miocene limestones, marls and breccias, but these are quantitatively of no importance.

The denudation estimate of the Brantas, obtained from the available data, is too low for two reasons. First of all in these rivers the silt-content of the bottom water is considerably higher (about 70 $^0/_0$) than that of the surface water, whereas in all the other rivers examined the one or the other is richer in silt, without any assignable constant ratio. Now considering that the silt-estimates mostly concern the superficial water — specimens of bottomwater were taken only about six times per month — the denudation value obtained for the Brantas-system must be some tens of per cents below the truth. Secondly the quantity of water carried past the place of observation (6.5 10^9 m^3) is slight as compared with the total rainfall in the system (25 10^9 m^3), even though we make allowance for the enormous evaporation in riversystem abounding in sawahs and in complicated rivercourses.

The Banjuputih gathers its supplies solely from the young volcanic massif of the Idjen. The denudation value of this river will be too low on the one hand, because the quantity of rainwater (1,9 10^8 m^3) carried past the place of observation, is a little too small in relation to the rainfall in the riversystem (4,5 10^8 m^3); on the other hand it must be a little too high, as among the transported "dissolved materials" there are many sulphates and sulphuric acid, which belong to the products constantly evolved afresh in the water of the Kawah Idjen, so that they do not constitute a factor in the denudation proper.

When summarizing what has thus far been said, we can divide the ten rivers, for which data were available, into five groups.

1. Rivers containing exclusively, or nearly so, volcanic rocks: Tjiliwong, Brantas, Banjuputih.

2. Rivers with predominating volcanic rocks, side by side with marls etc. Tjiwaduk, Tadjum.

3. Rivers with about an equal quantity of volcanic and clayey-marly rocks; Tjilamoja.

4. Rivers with predominating marly rocks: Djragung-Pengaron.

5. Rivers with very "mingled" systems; Seragu, Lusi.

I regret that values for rivers with systems containing marly rocks only were wanting, considering that for two such rivers, the Kali Tjolo and the Lotjo, descending from the marly region south east of Wirosari (East Semarang) — we had the disposal of full silt-estimates. We feel indebted to Mr. WEBER for his kindness to endeavour repeatedly to obtain the corresponding discharge-estimates, though he did not succeed.

It could be anticipated that the mean denudation values in Java would turn out to be relatively considerable. A high annual temperature, added to an abundant rainfall promotes a rapid weathering of the rocks; the rainfall yields large transporting watervolumes, which, owing to the marked land sculpture display great rapidity and force. In the east of Java a long drought with strong insolation accelerates the dislodging and crumbling of the rocks; the prevailing rocks (marls, concretionary shales and volcanic tuffs, breccias and agglomerates) are readily weathered and the layer of humus is — though not at all inconsiderable — much less compact than in other less cultivated tropical islands.

In tabulating the extent of denudation, we shall group the rivers into divisions according to the geological condition of their basins and shall give for every river the obtained value of annual denudation, adding in another column the figures between which, with much probability, the real values of annual denudation must lie; in doing so we have availed ourselves of the above speculations on the accuracy of the figures obtained.

I have not been in a position to consult original literature on dates of denudation in other countries, so that for comparisons I was restricted to data in older and newer handbooks.

In any case denudation in Java seems to proceed very rapidly. In calculating the duration of the American palaeozoicum C. D.

WALCOTT[1]) has assumed an average yearly denudation of 1 foot in 10000 years or about 0,03 mm. per annum, stating at the same time that the maximal annual denudation was then held to be 1.5 mm. (1 foot per 200 years). This maximum is even surpassed by the Seraju, Djragung and Pengaron; the average rate of denudation, admitted by geologists, is surpassed some times by the Tjiliwong, in whose system the clastation of rocks proceeds much more slowly than is the case with some other Java-rivers that have been examined.

Systems built up entirely or nearly so of volcanic rocks	Obtained Annual Denudation (mm.)	Actual Annual Denudation (mm.)
Tjiliwong	0.1	0.1—0.15
Brantas	0.28	0.35—0.6
Banjuputih	0.35	0.3—0.4
Systems with predominating volcanic rocks		
Tjimanuk	0.42	0.4—0.8
Tadjum	0.31	0.3—0.4
Systems with counterbalancing volcanic and clayey marly rocks		
Tjilamaja	1.4	1.0—1.4
Systems with predominating clayey marly rocks		
Djragung	1.6	1.6—2.5
Pengaron	4.3	3.7—5.0
"Mingled" systems		
Lusi	1.05	1.0—1.4
Seraju	1.6	1.4—1.8

1) C. D. WALCOTT, Journ. of Geology. I. Chicago. 1893. Quoted from E. DACQUÉ. Grundlagen der Palaeogeographie. Jena 1915.

GRABAU [1]) fixes the rate of denudation for the Mississippi system at 1 foot in 4640 year or 0,07 mm. per annum, for the Ganges at 1 foot in 1751—2628 years or about 0.15 mm. per annum.

In 1877 1177000 m.³ of matter was carried past Tetschen on the Elb. This gave a yearly denudation of about 0.03 mm. [2]).

These instances show that the rate of denudation in Java far surpasses that of the rivers studied thus far. This conclusion also holds for a comparison with other basins, the data for Java, however, deserve further consideration.

The above summary clearly shows that the rate of denudation depends largely on the geological condition; that it is smallest in volcanic regions and gradually increases, according as in a system the volcanic rocks are superseded by the miocene clays and marls. In the Pengaran system — where by no means only miocene marls occur — denudation progresses thirty times more rapidly than in the Tjiliwong system, composed entirely of volcanic rocks. Among the given factors, which may contribute theoretically to the high annual denudation the nature of the rocks appears to be of paramount importance.

The influence of the rainfall is evidently vere slight; the Tjiliwong system with an amount of rainfall of 4000 m.m. has a much smaller yearly denudation than the Lusi-system with only 2000 m.m.

Nor is the influence of the relief of the country as great as might a priori be supposed: the Tjiliwong and the Banjuputhi systems with their marked relief have a considerably lower annual denudation than the Lusi with a relief smaller than any other river examined.

The exceedingly great difference of the carrying power of the various rivers in the wet and in the dry monsoon is very striking. In this respect the Kali Djragung is most remarkable. In the month of January — in the middle of the wet season — of the year of observation it transported more than 13300 tons of suspended matter, in the month of August — in the middle of the dry season — only 40 tons.

J. WALTHER [3]) has stated that in desert regions the rare but catastrophic rains can act rather powerfully in the clastation of mountains. We are a priori inclined to assume for the humid tropics a more even distribution of denuding forces for the whole year, but

1) W. GRABAU. Principles of Stratigraphy. New-York. 1913. p. 247—248.

2) H. CREDNER. Lehrbuch der Geologie. IX. Auflage. 1902.

3) J. WALTHER. Das Gesetz der Wüstenbildung. 2 Auflage. 1912.

a study of the combined table tells us that also here the effect of catastrophic rains which occur rarely, may be very great.

If we wish to know how the denuding agents are working in certain regions we shall have to confine ourselves to small river-systems, as in the larger ones now in this, now in that tributary heavy rains will fall, whose local influence is of necessity distributed over the whole system and is consequently enfeebled. Of the rivers examined the Djragrung and the Pengaron have the smallest systems resp. 101 and 41 km². It now appears that the maximal silt-content, in these rivers, transported on one day, is resp. 31 °/₀ and 18 °/₀ of the annual transport, while in either rivulet the 10 largest spates carry off resp. 75°/₀ and 63°/₀ of the annual transport, a conclusive evidence of the catastrophic action of the heaviest rain-storms More striking figures may perhaps be obtained from available observations of still smaller systems, judging from the well-known local nature of many violent tropical cloud-bursts.

Still it would not do to assume such a relatively important action of the heaviest rainstorms for all rivers in Java. This action will no doubt be most significant in Central and Eastern Java, where a great contrast prevails between the wet- and the dry-monsoon, it will be much less in Western Java with a more even rainfall so that the Tjiliwong and the Tjilamaja — rather small rivulets — carried along in their 10 heaviest bandjirs only 11.2 °/₀ and 30 °/₀ of the annual transport.

From what has now been said it will be seen that the annual denudation in the predominantly volcanic regions of Java is a number of the order of 0,5 mm., whereas in the regions of the sedimentary deposits the average annual denudation will amount to about 2 mm. These values give rise to the following speculations:

The folding of the neogene in Java occurred on the borderline between pliocene and quaternary, perhaps still in the latter. The Trinil bone-beds held by some to be most recent pliocene, by others old quaternary — have still partaken of the folding. This is hardly discernible in the environs of Trinil itself, but quite unmistakable in the environs of Modjokerto and Surabaya, where volcanic sands, agglomerates and tuffs, (petrographically quite similar to the Trinildeposits and including locally also bones of Stegodon) exhibit a distinct and even a rather great plication[1]).

R. D. M. Verbeek[2]) has indeed endeavoured to demonstrate that

[1]) L. Rutten Verhandel. Mijnb. Geol. Genootschap. III, p. 149—151. 1916.

[2]) R. D. M. Verbeek. Molukken-Verslag. Jaarb. van het Mijnwezen. 37. 1908 Wetensch. Gedeelte. p. 783 seq.

the bone-beds south of the G. Pandar overlie unconformably the recent tertiary marls — though he also admits a slight upheaval of these beds — but first of all the unconformability indicated by him in a profile is not at all in keeping with his own researches (inclination of the marls far too sharp); secondly, the supposed unconformability is based on the junction of two bonebeds that are wide apart from each other (Dungbrubus and G. Bulak), though only a minute study of details can tell us whether there is, or there is not, any fault between the finding places; anyhow their junction is not borne out by local observation.

The subsidence on the boundary between pliocene and quaternary gave rise to upheavals of the order of 1000—2000 m. in Eastern and Central Java. The mountain range thus engendered has been almost completely peneplaned in the quaternary, after which, on the thus formed peneplain, the most recent formations of some volcanoes i.a. of the Ungaron and the Merbabu have been deposited, as may be beautifully seen on the railway-line between Kedung Djati and Willem I [1]). After a, probably vertical, very young upheaval the present valleys penetrated far into the marl-zone through the overlying volcanic deposits.

The subsidence was, then, succeeded by a denudation of 1000—2000 Meters, which with an annual denudation of 2 mm. must have required a period of 500000--10000000 years, the length of the quaternary period in Java. This very rough estimate does not badly correspond to a recent estimate of the length of the quaternary period in Europe, fixed by PENCK in 1908 at 500000 years [2]).

The average height of the volcanic massifs (without reckoning the peaks) in Java may be fixed at a number of the order of 1000 m. With a yearly denudation of 0.5 mm. this would point to total disappearance of the present volcanoes of Java in 2000000 years. If, in this connection, we bear in mind that it has generally been admitted that the Tertiary has lasted many times longer than the Quaternary, it is easy to conceive that "old-miocene" volcanoes in Java can hardly be expected to possess discernible crater-rims. Nevertheless VERBEEK and FENNEMA [3]), have indicated discernible crater-rims for numerous volcano-massifs — which they pretend to be "old-

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[1]) I must advance here that though I am personally acquainted with this part of Java, I should hardly have observed these features of the landscape on a short excursion, if the results of an inquiry by Dr. W. HOTZ, who made a geological map of this region in 1911, had not come to my knowledge.

[2]) In E. DACQUÉ, l.c. p. p. 273.

[3]) R. D. M. VERBEEK and R. FENNEMA l.c.

miocene". Now it is evident from the foregoing that in that case either the volcano-massifs cannot be old-miocene, or the crater-rims do not exist. This statement is of some moment also for regions in other islands. VERBEEK [1]) has asserted in his study of the antiquity of the eruptive rocks in Amboina that they cannot be tertiary, since they are entirely without volcanic shape — in contradistinction to old-miocene and perhaps even older volcanic massifs in Java. From what has been said in this paper it is evident that *this* argument for the antiquity of the Amboinites carries no weight.

Sindanglaja, July 27, 1917.

[1]) R. D. M. VERBEEK, Over de geologie van Ambon. I and II. Verh. Kon. Akad. Wetensch. VI. 7. 1899, VII. 5. 1900.

	Dissolved matter in milligrams pro Liter											
	January a	February b	March c	April d	May e	June f	July g	August h	September i	October j	November k	December l
TJILIWONG	71.2			65.2	78.0	79.2	74.3	72.6				
TJILAMAJA		121			134	134	161		176	186		141
TJIMANUK		131.6	118.8	125.0		149.0	165.0	187.0		117.0		
TADJUM			85.2			119.6	95.2	91.8			98.2	111.4
SERAJU	115.6	108.0				128.4	140.8	140.2			135.4	118.6
PENGARON		247.6		205.4			245.4	253.6		241.6		
DJRAGUNG		303		244			317	342		303		
LUSI			198				411		620			264
BRANTAS		184	195			212	243	243				
BANJUPUTIH		469		652		578			539	572		

	Highest quantity of mud in mgr. per Liter m	Lowest quantity of mud in mgr. per Liter n	Highest produce in m^3 per second o	Lowest produce in m^3 per second p	Highest transport in kg. per second q	Lowest transport in kg. per second r	Quotient q/r s	Highest monthly transport in tons t	Lowest monthly transport in tons u	Quotient t/u v	Highest daily transport in percents of yearly w	Lowest daily transport in percents of annual transport x	Transport of the 10 greatest spates in percents of annual transport ij
TJILIWONG	1638 21. II. a.m.	3 4. X. p.m.	- 22 22. III. a.m.	1.75 16. IX.	18.018 21. II. a.m.	0.0135 4. X. p.m.	$\pm 0.13 \times 10^4$	3529 November	224 August	15	± 2.2	0.01	± 11.2
TJILAMAJA	8120 12. III. a.m.	47 28. VIII. p.m.	247.1 3. IV. a.m.	1.46 30. VIII.	996.4 22. XII. a.m.	0.0837 28. VIII. p.m.	$\pm 1.2 \times 10^4$	200 000 April	800 August	250	± 4.1	0.001	± 30
TJIMANUK	9397 24. I. a.m.	15 30. VIII.	696.17 5. III. p.m.	3.2 30. VIII.	1880 22. III.	0.048 30. VIII.	$\pm 4 \times 10^4$	? 1 100 000 March	1040 August	1058	± 5.1	0.00016	± 36
TADJUM	4630 26. XII. p.m.	4 23. IX. p.m.	98.09 19. V. a.m.	2.159 X.	182.3 19. V. a.m.	0.0098 23. IX. p.m.	$\pm 1.8 \times 10^4$	26 000 March	110 September	236	± 9.3	0.0011	± 46.6
SERAJU	7432 1. III.	18 13. X. a.m.	2990.1 10. I. a.m.	73.1 14. X. a.m.	6244.0 28. II. a.m.	1.35 13. X. a.m.	$\pm 0.46 \times 10^4$	2 530 000 March	9000 September	281	± 5.4	0.0015	± 29
PENGARON	42995 21. XI.	18 6. V.	92.6 29. IV.	0.4 VIII.	1656.87 29. IV.	0.0198 6. V.	$\pm 8.3 \times 10^4$	148 500 December	320 July	451	± 18	0.00008	± 63
DJRAGUNG	18807 12. XII. p.m.	10 22. VIII. p.m.	111.3 26. I. p.m.	0.04 26. IX.	1459.1 26. I. p.m.	0.00056 26. IX.	$\pm 260 \times 10^4$	> 133 000 Jan.	40 August	3325	± 31	0.00001	± 75
LUSI	15735 7. VIII. p.m.	8 6. VII. a.m.	> 320 8. I.	0.1 Aug./Sept. sev. days	1391.2 28. XII. p.m.	0.003 6. VII. a.m.	$\pm 48 \times 10^4$	? 750 000 Jan.	400 September	1875	± 5.5	0.00005	± 30
BRANTAS	9830 10. IV. p.m.	41 22. IX a.m.	863.2 21. II.	31.7 3. XI.	4915.0 16. IV. p.m.	1.51 23. X.	$\pm 0.33 \times 10^4$	1 390 000 April	7500 October	185	± 4	0.002	± 17
BANJUPUTIH	24000 8. II p.m.	39 15. X. a.m.	?	5.0 sev. days	?	0.206	?	? 14 000 Jan.	1250 October	11	?	?	?

	Annual transport of mud in tons z	Annual transport of dissolved matter in tons aa	Total annual transport in tons and m^3. bb	Extent of the river-basin above place of observation in □ km. cc	Annual denudation in m.m. dd	Average yearly fall of rain in mm. ee	Total annual fall of rain in river-basin above place of observation in m^3. ff	Annual quantity of water in m^3 streaming along place of observation gg	Stones in riverbasis Observations. hh	Year
TJILIWONG	± 19000	± 18 000	± 37 000 T. ± 14 800 M^3.	± 130	± 0.1	± 4000	$\pm 5.2 \times 10^8$.	$\pm 2.6 \times 10^8$.	Andesites etc. Place of Observation: Katulampa.	1. XI. 1912— 31. X. 1913.
TJILAMAJA	± 750 000	± 80 000	± 830 000 T. ± 332 000 M^3.	± 225	± 1.4 (too high)	± 3000	$\pm 6.8 \times 10^8$.	$\pm 5.6 \times 10^8$.	Half marls etc., half volcanic stones. Pl. of Obs.: Sungapan.	13. VI. 1915— 12. VI. 1916.
TJIMANUK	> 2400 000 < 4000 000	> 300 000 < 450 000	> 2700 000 T. < 4450 000 T. > 1080 000 M^3. < 1780 000 M^3.	± 3000	0.36—0.59 (too low)	3000—3500	9×10^9—10×10^9	2×10^9—3×10^9.	Nearly all Andesites etc. Pl. of Obs.: Rentang.	?
TADJUM	± 120 000	± 44 000	± 160 000 T. ± 64 000 M^3.	± 210	± 0.31	± 4000	$\pm 8.4 \times 10^8$.	$\pm 4.4 \times 10^8$.	Most Andesites etc.; Some marls. Pl. of Obs.: Tipar.	21. II. 1914— 20. II 1915
SERAJU	± 9600 000	± 1130 000	± 10700 000 T. ± 4300 000 M^3.	± 2700	± 1.6	± 5000	$\pm 13.5 \times 10^9$.	$\pm 9.4 \times 10^9$.	Nearly all formations of Java. Pl. of Obs.: Mandirantjan.	21. II. 1914— 20. II. 1915.
PENGARON	> 360 000 < 500 000	± 16 000	> 380 000 T. < 520 000 T. > 152 000 M^3. < 208 000 M^3.	± 41	3.7—5	± 2600	$\pm 1.1 \times 10^8$.	0.6—0.8×10^8.	Most marls; some volcanic stones. Pl. of Obs.: Kali Kajen.	23. II. 1913— 31. I. 1914.
DJRAGUNG	< 350 000 > 45 000	± 27 000	± 400 000 T. ± 160 000 M^3.	± 101	1.6 (too low)	± 2600	$\pm 2.6 \times 10^8$.	0.8—1×10^8.	Marls and volcanic stones. Pl. of Obs.: Sapen.	12. II. 1913— 31. I. 1914.
LUSI	> 1700 000 < 2500 000	± 170 000	± 2250 000 T. ± 900 000 M^3.	± 860	1.05	± 2000	17.2×10^8.	6—10×10^8.	Marls, limestones, quaternary. Pl. of Obs.: Kalang Losari.	?
BRANTAS	± 5800 000	± 130 000	7100 000 T. 2840 000 M^3.	± 10 000	0.28 (too low)	± 2500	25×10^9.	$\pm 6.5 \times 10^9$.	Nearly all volcanic stones. Pl. of Obs.: Modjokerto (Lengkong).	1914.
BANJUPUTIH	> 70 000 < 100 000	± 115 000	> 185 000 T. < 225 000 T. > 74 000 M^3. < 90 000 M^3.	± 225	0.3—0.4	± 2000	4.5×10^8.	$> 1.9 \times 10^8$.	Volcanic stones. Pl. of Obs.: Lewung.	8. III. 1915— 7. III. 1916.