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Results of the Austrian-Ceylonese Hydrobiological Mission 1970 of the 1st Zoological Institute of the University of Vienna (Austria) and the Department of Zoology of the Vidyalankara University of Ceylon, Kelaniya

PART II—HYDROCHEMICAL STUDIES ON MOUNTAIN RIVERS IN CEYLON

By

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INTRODUCTION

The chemical components of tropical freshwater of the wet region are influenced very strongly by way of geology and climate. The dependency on these factors is very clear and not further complicated by seasonal effects. Characteristic of the wet region is the extreme poverty of dissolved electrolytes in areas of maximal rainfall corresponding with the crystalline series (granite, quartzite, etc.)

These conditions are found in the SW of Ceylon and on the central highland. GEISLER (1967) published details about the hydrochemistry of the different Ceylonese rivers in the altitudes of 30–480 meters above sealevel. The acidity of these rivers is not extreme and seems to be comparable with the " eau humique partiellement neutralisee " of the Congo-region (BERG 1961). This water-type is described in connection with the degree of neutralization of Humus-acids.

GEISLER compared his results also with those of SIOLI (1955) on Amazonian waters and he concluded that the high content of NH_4 is the result of reduced nitrification. Otherwise the Ceylonese rivers are more of the " clear water-type " (especially the mountain-rivers) and this type shows usually complete oxidation. It is suspected that there are close connections between NH_4-content and the content of Humus-acids. Therefore the analysis of Humus-acids completes this study.

The main subject of this investigation are the highland-rivers and the influence of extremely soft water, with unusual little contents of elctrolytes, to organisms. Accordingly, the content of aggressive CO_2 was measured, as a main effect of very soft water to calceous shells of gastropods.

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Methods

Field measurements were made as follows :—

P–.	—	Merck (Special indicator 4,0—7,0) Merck (liquid indicator)
conductivity	—	field apparatus with accoustic regulation
Alkalinity	—	demand on n/10 HCl against Methylorange
total hardness	—	1^0 German hardness=10 ppm. CaO/liter Merck—reagents (Titriplex, Ethylendiamintetra-acetic acid)
aggressive CO_2	—	measured as Alkalinity before and after the addition of marble powder (HEYER-METHOD)
free CO_2	—	titration with NaOH against phenolpthalein
NO_2	—	a- naphtylamin

500ml. samples were taken for a further analysis in the laboratory. PH-, and conductivity-measurements were repeated. Further methods :—

$Ca^{\cdot\cdot}$	—	complexometric (EDTA), Calcon (MERCK pp. 72)
$Mg^{\cdot\cdot}$	—	complexometric (EDTA) (MERCK, pp. 72)
$Na^{\cdot}$	—	flame photometer
$K^{\cdot}$	—	flame photometer
$Fe^{\cdot\cdot}+Fe^{\cdot\cdot}$ (Total Iron)	—	1,10 phenantrolin, photometric (FREYER, pp. 41)
$Al^{\cdot\cdot}$.	—	eriochromecyanin, photometric (VGB, pp. 260)
NH_4 .	—	Nessler-reagent
NO_3 ,	—	measured as NO_2 (reduction) a-naphytlamin (FREYER, pp. 21)
Cl '	—	mercurinitrate, diphenylcarbazon (VGB, pp. 134)
SiO_2	—	silicomolybdane-complex, photometric (VGB, pp. 266)
P_2O_5	—	vanadatmolybdat-reagent (MERCK, pp. 69)
F '	—	-ion-selective electrode (ORION)
total Humus acids	—	direct adsorbtion (300 um.) (VGB, pp. 358)
Humus acid A	—	direct adsorbtion (366 um.) (KURAPKAT, VGB, pp. 358)

Morphology and Climate (Fig. I)

The interior of the Island (area 65,610 km²) is occupied by the Central Highlands, a complex of plateux, mountain chains and basins, at a general elevation of 1,400 to 1,800 m.

The highland is surrounded by two peneplains the lowest which extends from the coast inland (the lowland) where it rises to 100–150 m. above sea level, The second peneplain (the upland)has a general elevation of 500–700 m., at some places it is irregular and heavily eroded.

The highland may be divided into three portions—the Knuckles Group to the North, the Central Massifs and the Sabaragamuwa Ridges to the Southwest.

SAWICKY (1925) mentioned 4 peneplains (see 1.4) :

first, peneplain (lowland, Vijaya-stratas) 30–90 m.
second, peneplain (upland, Vijaya+Khondalite) 500–700m.
third, peneplain (Hatton plateau, Khondalite) 1,000–1,400 m.
fourth, peneplain (Nuwara Eliya, Khondalite) 1,500–2,500 m.

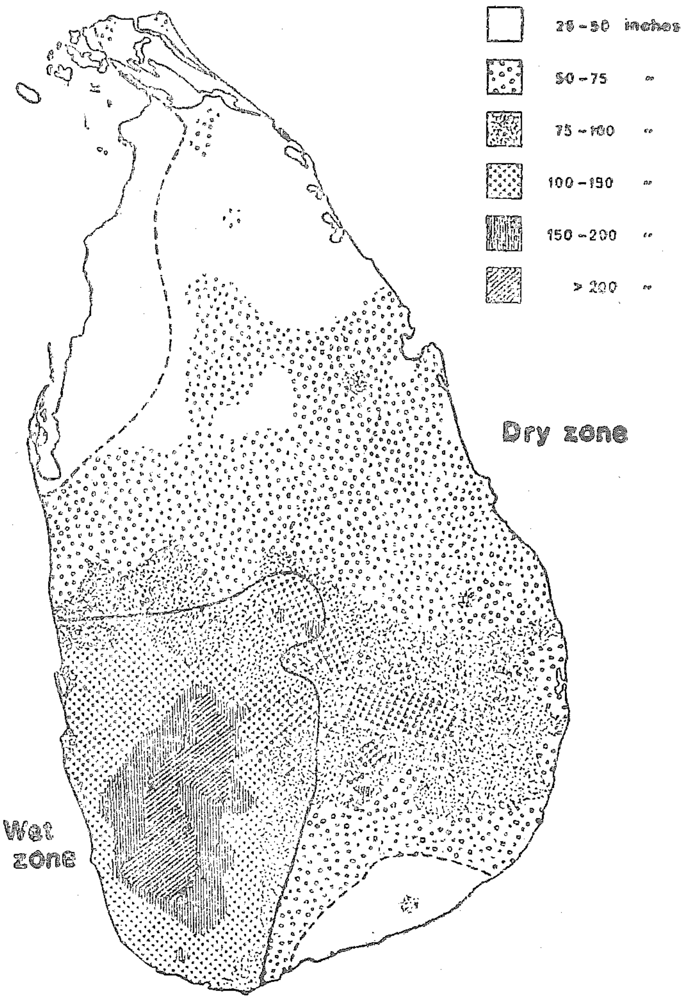

Fig.—Annual rainfall in Ceylon, according to Rainfall May 1955 of Survey Deparment, Ceylon Thick line encloses the wet zone. Broken lines enclose the very dry areas in northwest and southeast. (after Brinck 1971)

The highest elevation is top of Pidurutalagala near Nuwara Eliya (2,524 m. above sea level).

Ceylon is situated within the equatorial belt of calms. The intensity and narrow amplitude of insolation is an important factor controlling the climate. There are only slight seasonal variations in temperature, air humidity and day length.

The ascending of the main winds—Southwest monsoon (May-August) and Northeast monsoon (from the end of November to February) on the flanks of the Central massifs gives a very differentitated distribution of rainfall (Figure 1). The annual rainfall in Ceylon is according to the Rainfall Map of 1955 of the Survey Department, Ceylon (BRINCK 1971).

The annual mean temperature at station level for a period of three decades was 27,2°C in the lowlands (Colombo, Jaffna, Hambantota, Anuradhapura), 24.4°C in the upland (Kandy) and 15,4°C in the highland (Nuwara Eliya). The mean temperature of the months varies only slightly ; the yearly amplitude is only 1.7-1,8°C in the coastal lowland (Colombo), 2,7°C in the upland (Kandy) and 2,4°C in the highland (Nuwara Eliya). The coldest month is December or January with about 26,1°C in the lowland (Colombo), about 23,3°C in the upland (Kandy) and 14,4°C in the highland (Nuwara Eliya).

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Similarly the mean relative humidity varies only slightly : lowland—Colombo : 68-79% RH in the daytime, 87-93% at night ; upland—Kandy 60-76% RH in the day time, 87-94% at night ; highland—Nuwara Eliya : 60-84% RH in the daytime, 88-93% at night.

You can separate " the wet zone " (with 2,000mm. rainfall a year) where it rains all through the year (Figure 1).

The rest of the country is " the dry zone " with a dry season which lasts several months in the North.

The average annual rainfall varies about 1,000 mm. on the Northwest coast to more than 7,000mm. in front of Adam's Peak.

Much of the rain is produced by the strong convection currents—sudden heavy showers and thunderstorms, less by migration of low pressures. Most important to the SW and the Central highlands is the Southwest monsoon in June, July and August, while the northeast monsoon in December and February affects only the Northeastern lowland, upland and the adjoining flanks of the highland.

The above data have been taken from BRINCK, ANDERSON, and CEDERHOLM (1971).

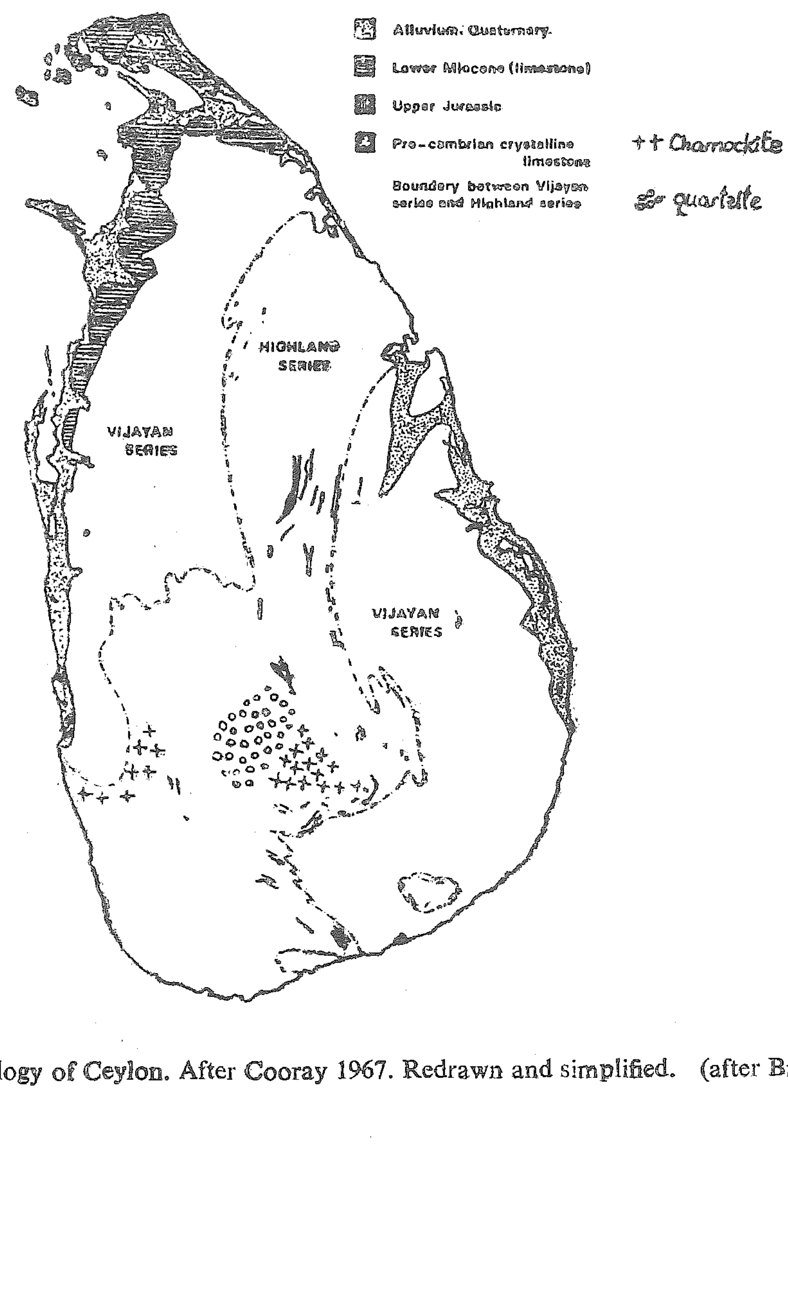

Fig.—Geology of Ceylon. After Cooray 1967. Redrawn and simplified. (after Brinck 1971)

Geology (Fig· 2) and soils

Ceylon is a detached part of the continental Deccan plateau of ancient precambrian crystalline rocks, and only the peninsula of Jaffna and the Northwest coast is covered by miocene limestone. The crystalline precambrian stones are seperated into two different regional series. The most important material, especially on the East-side, consists of quartzic biotite-gneiss (*Vijaya-series*). In North-South direction you have a broad central zone of metamorphic sediments—quartzites, Schists and crystalline jurassic limestones which are called *Khondalite-stratas* (*Highland series*), FERNANDO (1948). Both series continue in South India.

The biotite-gneiss from Ceylon is adequate to the Bengal-gneiss, the Khondalit is adequat to those from Madras and Orissa.

The Charnockites in the Central Highland series give connections to formations formations in Madagascar and South Africa. All these data are taken from SIEVERS (1964).

COATS (1935) estimated the amount of archaic crystalline stones to be 9/10th of Ceylon. A full treatment of the geology of Ceylon is given by COORAY (1967).

Alluvial soils, mainly sand, clay and silt cover relatively large areas of Ceylon, particularly along the coast and at the outflow of the large rivers. In the nothwestern dry parts of the island you find red-yellow soils with a high cation exchange capacity (widespread on coastal alluvia and miocene limestones). The dominating soils in the dry zone (below 2,000 mm. rainfall) are reddish brown earth, derived from basic or neutral rock material. On the acid gneisses of the South-East, where there is a deficiency of ferromognesian minerals, non-calcic soils develop (BRINCK 1971).

In the wet zone podsolic soils predominate, independent of the subsoil parent material. In the high altitude grassland (patana) and the fernlands there is a dark humic horizon, while laterization occurs particularly in the western part of the zone. MOORMAN and PANABOKKE (1961).

Geochemical conditions (WEDEPOHL 1967)

Weathering of granitic rocks commences by mechanical gravelling—first of all there is the bleaching of biotites with the loss of iron. Later the iron seperates again in gaps (geothite). Hydrothermal decomposition of basaltic minerals confirms that hot acidic water is much more effective in exchanging substances than alkaline water.

Granites have the tendency to lose Pb, Zn, Cu during low temperature decomposition processes. Mechanically gravelled granites could lose, after the bleaching of their biotites more than one half of their content of these heavy metals. The magmatic and metamorphic stones are most sensitive to reactions with water since they do not originate under surface conditions. Na, Ca, Si are washed out from the magmatic stones and transported to the ocean. Quartz in resistant to weathering and decomposition and therefore its percentage in the stone increases.

During the progressive decomposition of granite—chlorite, vermiculite and other similar minerals come in the place of biotite, while potassium (K) gets lost.

KOESTER (1961, cit. WEDEPOHL) studied a lateritic soil profile above granite. He found an enrichment of Fe^{3+} Ti, Al, Zr, Cr, H_2O and P—at the cost of the surroundings. This increase is compensated by the great loss of Mg, Ca and alkali-metals (Na, K, Li) Mg and Ca can be completely washed out from some sites. The rather little loss of Si results from its fixation in the form of kaolinite. Solution and migration of kaolin-substances can be proved in this profile.

The intensity of decomposition of a stone during lateritization and the local separation of Al and Fe^{3+} by the formation of their own minerals can occur under the conditions of tropical climate. SIGWALDSON (1959, cit. WEDEPOHL) pointed out that the decomposition of silicate is accelerated in acidic water under extreme conditions and the whole substance except SiO_2 and Al gets lost. Alkali-metals get lost in the furtherst decomposition site from the course, alkali-earth metals get lost (are washed out) in a medium site, while iron and most of Al only dissolve near transport passages.

	Granite	*Granodiorite* (NOCKOLDS 1964)
SiO_2	73,1	67,4
TiO_2	0,30	0,57
Al_2O_3	13,9	15,8
Fe_2O_3	0,84	1,3
FeO	1,5	2,6
MnO	O,06	0,07
MgO	0,42	1,6
CaO	1,1	3,6
Na_2O	3,2	3,8
K_2O	5,3	3,1
P_2O_5	0,17	0,21

Ba, Rb and Pb are enriched in granitic stone, while Ni, Cr, Co are more in basaltic rocks. In the North of Ceylon you find miocene-limestone, but the regions of the highland series contain only very old pre-cambrian crystalline limestone. In this connection mention should be made of the *increase of the Mg-content in old geological calcareous sites. This relation of Mg-content to the age* of stones could be found even in relatively young material. Analysis of 32 devonic limestones showed a MgO content of 1,3%, the same of 45 jurassic limestones is 0,9% and of 16 chalk formations is 0,5%.

Limestones consist beside carbonates, more or less quantities of silicates. Secondary ingredients are especially Sr, also Mn, Ni, Zn, Pb, Ba.; F and P probably occur as their own minerals, Some organic shells contain specific elements (for example, molluscs contain Mn, Fe), LEUTWEIN WASKOWIAK (1962) cit. WEDEPOHLis as follows:—

Mean values for 345 limestones (CLARK 1924 cit. WEDEPOHL) is as follows :

SiO_2	5,2	MnO	0,05	K_2O	0,3
TiO_2	0,07	MgO	7,9	*H_2O*	0,8
Al_2O_3	0,8	CaO	42,6	P_2O_5	0,09
Fe_2O_3	0,5	Na_2O	0,05	CO_2	41,6
FeO	—				

Normal rainwater contains mean values of dissolved ingredients in ppm-ranges, river-water those in 10 ppm. range and sea-water in % range. Proportions of dissolved components in rain water, river-water and sea-water undergo cyclic changes. The cyclic content of Na in river-water is at least 1,9 ppm. (CONWAY 1942 supposed a cyclic content of 3,3 ppm. Na). Specific traces of elements and substances in rainwater originate from the soil (Si, Ca, K, Mg, Na, HCO_3'), some from industrial processes (SO_4'' HCO_3') and some from the atomosphere (HCO_3' H_2CO_3). SO_4'' may also originate fiom bacterial H_2S-oxidation in the sea.

	Rainwater (SUGAWARA 1963)	River-water (CLARKE-CONWAY 1942)	Sea-water (all cit. WEDEPOHL 1967)
Na	1,1	2,5 (5,8)	10,560
K	0,26	2,1	380
Ca	0,97	20	400
Mg	0,36	3,4	1270
Cl	1,1	0,6 (5,7)	18980
SO_4	4,2	11 (12)	2650
$HCO_3' + H_2CO_3$	1,2	35	140
Si	0,83	8,1	0,05—5,0

Location of the different stations where water samples were collected. (Tables 1 to 6, see also Part I of this series)

Table 1.—Kelani-Ganga, lower course (0-20 meters above sealevel)

FC 38 Kelani-Ganga near Hanwella. Running through plantations. No shadow. Br 50-100m. Te. 27,2°C (3 p.m.).

FC 33A Kelani-Ganga near Colombo —Kelaniya.

FC 33B Kelani-Ganga near the sea, estuary.

FC 33C Beira lake near Colombo.

Table 2·—Kalu-Ganga, Kelani-Ganga, middle course (30-100m· above sealevel)

FC 12 Kalu-Ganga upstream near the town of Ratnapura ; deep valley with plantations and forest. Br. 20-30 m., Curr. 0-30-100cm./sec., Te. 26,1 (10 a.m.)-26,6 (11.30 a.m.)°C.

FC 13 Upper reaches of Kalu-Ganga at Malwala, running through plantations, no shadow. Br. 15-20m., Curr. 50-75, Te. 26,7-26,3°C (13-30-16 p.m.).

FC 15 Ira Handha Pana-Dola, a torrent and tributary of Kalu-Ganga, running through plantations, no shadow. Br. 2-4m., Curr. 30-50-100, Te. 18,-7 20,7°C (9,30-12,00).

FC 34 Bibili-Oya, an affluent of Kelani-Ganga, near Kitulgala, partially shady. Br. 6-10m., Curr. 50-100, Te. 25,4- 15,8°C (2-4 p.m.).

FC 37 Kelani-Ganga near the Kitulgala resthouse. Br. 30-50m., Curr. 50-100, Te. 24,3-26,4°C (7 a.m.-6 p.m.).

Table 3.—Upper course region of Kalu-Ganga, Kelani-Ganga, Gin-Ganga (500-800m. above sealevel) and Nilwala-Ganga

FC 5 Campden Hill-Dola, a torrent running between tea plantations, no shadow· Br. 3-10m., Curr. 75-100, Te. 24,1-24, 7°C (9-11 a.m.).

FC 6 Kiriwel-Dola, upstream near the tea-factory of Enselwatte-Group. Affluent of Gin-Ganga, like the Campden Hill-Dolal. No shadow. Br. 5-10m., Curr. 30-75, Te. 23,8°C (3 p.m.).

FC 8 Nagahaketa-Dola, Diyadawa, a torrent running through forest and plantations, partial shady. Affluent of Nilwala-Ganga. 3-5m., Curr. 50, Te. 25, 1-27, 3°C (9,30-12,00).

FC 14 Upper reaches of Kalu-Ganga, south flank of Adams Peak, near Carney-Estate deep gorge in primary rain-forest, very shady. Br. 2-10m., Curr. 75-100, Te. 22 8-23, 8°C (10-12).

FC 35 Hal-Oya near Ginigathhena, a fountain-torrent of Kelani-Ganga. No shadow. Br. 1-5m., Curr. 30-50-100, Te. 22,5-23, 1°C (9-11 a.m.).

FC 36 Rambuktpoth-Oya near Pitawela, a fountain, torrent of Kelani-Ganga, flowing through a deep gorge, no shadow. Br. 5-8m., Curr. 30-75-100, Te. 25,1°C (1 p.m.).

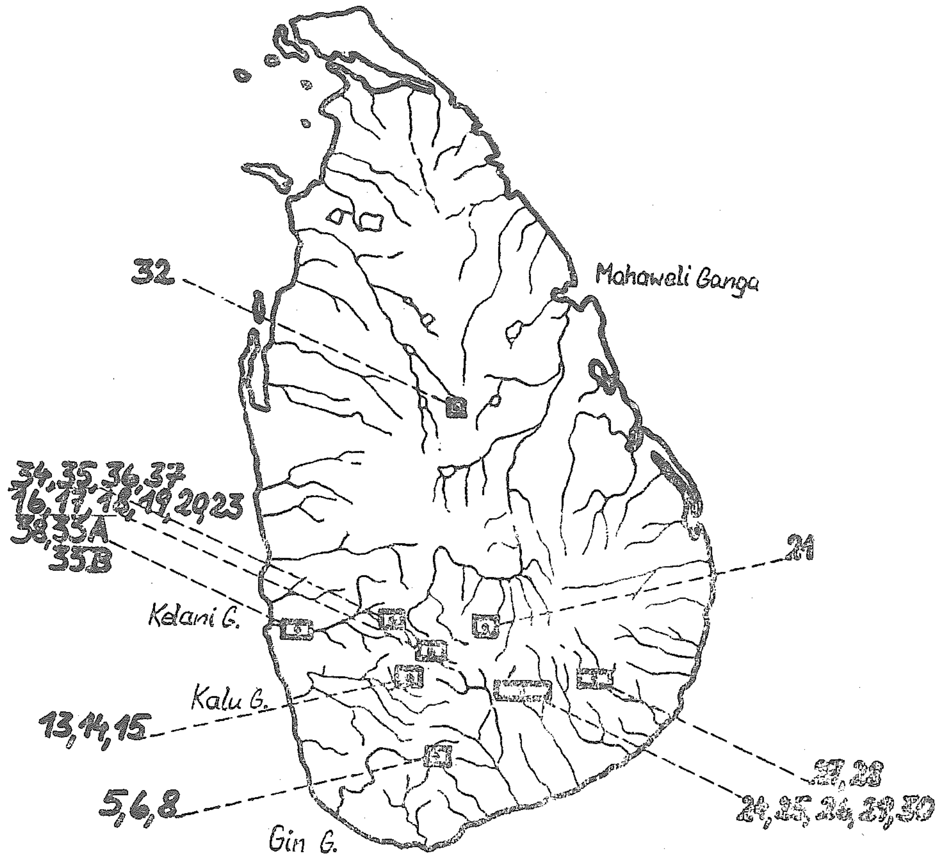

Fig. 3 Collecting Stations

Table 4.—Mountain region of Maskeliya and Nuwara Eliya (Source of Kelani-Ganga and Mahaweli-Ganga, 1,200-2,200m.)

FC 16 Mocha-Dola, a torrent running through the Adam's Peak-Estate (tea-plantations). No shadow. Br. 2-5m., Curr. 30-50-100, Te. 18,7-20, 7°C (9,30-12,00).

FC 17 Gartmore-Estate-Dola, a small torrent coming from the primary rain-forest. Peneplain of Adam's Peak region, altitude 1,850m., Br. 2-5m., Curr. 10-50-100, Te. 16, 1-17, 2°C (10-12 p.m.).

FC 18 Gartmore-Estate-Dola, downstream FC 17, below the waterfall-horizon in the Gartmore-Estate valley ; a torrent running through tea-plantatoins, no shadow. Altitude 1,500m. Br. 10-20m., Curr. 10-20-100, Te. 16,9°C (10 a.m.).

FC 19 An affluent of the Gartmore-Estate-Dola near the superintendent's bungalow ; a torrent running through tea-plantations, no shadow. Br. 2-3m., Curr. 50-100, Te. 15,3-19,3 (7 a.m. -4 p.m.).

FC 20 Maskeliya-Dola, north flank of the Adam's Peak chain. A torrent running in a deep gorge through tea-plantations and forest. Br. 5-8m., Curr. 10-30-100, Te. 18,3-19,9°C (11 a.m.-1 p.m.).

FC 20A Maskeliya-Barrage, flow out. Br. 20m., Curr. 30-70. Red sediment of Iron-hydroxide.

" Adam's Peak " : 150ft. below the top, little fountain near the path.

FC 23 Dick-Oya, a river near the road between Maskeliya and Hatton. Running through plantations and small forest. No shadow. Br. 5-10m., Curr. 75-100, Te. 18,6-20,8°C (11 a.m.-1 p.m.). Slightly polluted (more green algae).

FC 21 Hakgala-Dola, a small torrent running through the garden near Nuwara Eliya. Shadow. Br. 2m., Curr. 50-75, Te. 15,3°C (4 p.m.).

Table 5.—Region of the steep descent to the south of Hatton plateau (Horton Plains) 400-700m.

FC 24 Belihul-Oya near the resthouse no shadow. Br. 5-6m., Curr. 10-30-100, Te. 18,3-21,4°C (7 a.m.-5 p.m.).

FC 25 Kirikatu-Oya coming from Horton Plains in cascades. No shadow. Br. 5-8m., Curr. 20-100, Te. 18,8-19,6°C (9 a.m.-12).

FC 26 Veli-Oya, a torrent, no shadow. Br. 10-15m., Curr. 20-100, Te. 21-20,8°C; C4-(5 p.m.).

FC 29 Diyaluma-Falls coming from Horton Plains at World's End, below the cascades (450 ft.). Br. 10m., Curr. more than 1, Te. 20°C (5 p.m.).

FC 30 We-Ganga near Balangoda (near the Ratnapura-Belihuloya road) running over huge rocks between forest and paddy-fields. Br. 5-10m., Curr. 30-100, Te. 24,7-25,6°C (10 a.m.-12).

Table 6.—Water systems outside of the wet region (to SE and N of the mountains, 50-200m.)

FC 27 Kuda-Oya near Buttala in the South east of Ceylon, running through forest. Shadow. Br. 10-15m., Curr. 30-50-100, Te. 25,5°C (11 a.m.).

FC 28 Wetakei-Ela, a small torrent in the forest near Wellawaya with calcarous sinter on the stones. Shadow. Br. 1-2m., Curr. 30-50-100, Te. 23,9°C (2 p.m.).

FC 32 A small river in a forest, crossing the road between Habarane and Dambulla, in the West of Polonnaruwa. Shadow. Br. 1,5-3m., Curr. 30, Te. 25,5°C (6 p.m.).

Sinhalese " Ganga " means large river.
,, " Oya " means river.
,, " Ela " means stream.

TABLE 1

Kelani Ganga, lower course (0–20 meters)

Station		*FC* 38	*FC* 33*A*	*FC* 33*B*	*BeiraLake*
altitude (m.)		20	5	0	10
μS/cm. (conduct.)		27	42,6	288	2200
P_H (electrom)		6,45	6,50	6,40	7,10
$KMnO_4$—consump.		22,1	28,4	13,3	36,6
Humic acids	ppm	0,000	0,038	0,151	0,113
hardness° German		0,36	0,51	1,83	20
CaO	ppm.	2,52	2,90	1,60	148,8
MgO	ppm.	0,80	4,93	9,68	36,7
$Ca^{\cdot\cdot}$	ppm.	1,81	2,09	1,15	107,2
$Mg^{\cdot}$	ppm.	0,48	2,96	5,81	21,6
$Na^{\cdot}$	ppm.	2,00	4,80	1,00	222,5
$K^{\cdot}$	ppm.	0,95	5,00	3,50	31,0
$Fe^{\cdot\cdot}Fe^{\cdot\cdot\cdot}$	ppm.	0,014	0,03	0,004	0,004
$Al^{\cdot\cdot}$	ppm.	0,03	0,04	0,09	0,06
$NH_4^{\cdot}$	ppm.	0,01	0,015	0,04	0,25
NO_2'	ppm.	0,00	—	—	0,01
NO_3'	ppm.	0,162	0,123	0,210	3,00
Cl'	ppm.	2,84	7,38	85,2	745,5
F'	ppm.	0,057	0,063	0,049	0,076
P_2O_5	ppm	0,02	0,04	0,08	0,19
diss. SiO_2	ppm.	3,50	3,00	6.95	7,50
Alk. (HCO_3')	mval.	0,08	0,36	0,44	1,00

TABLE 2

Kalu Ganga and Kelani Ganga, middle courses (altitude 30–100 meters)

Station		*FC* 12	*FC* 13	*FC* 15	*FC* 34	*FC*37
altitude (m.)		30	80	100	80	64
μS/com. (conduct.)		46,2	41,5	25,5	18,2	33,4
p_H (field)		6,0	6,0	5,9	—	—
p_H (electrom.)		—	7,20	6,75	6,60	6,65
$KMnO_4$—consump.		—	19,1	17,6	18,3	15,8
Humic acids	ppm.	—	0,567	0,189	0,151	0,113
hardness° German		1,40	1,15	0,50	0,21	0,71
CaO	ppm.	8,40	6,38	2,35	1,01	4,48
MgO	ppm.	4,03	3,69	1,91	0,80	1,84
$Ca^{\cdot\cdot}$	ppm.	6,00	4,89	1,69	0,73	3,23
$Mg^{\cdot\cdot}$	ppm.	2,42	2,21	1,15	0,48	1,10
Na.	ppm.	—	1,90	2,30	2,00	1,80
$K^{\cdot}$	ppm.	—	0,80	0,80	0,35	1,10
$Fe^{\cdot\cdot}Fe^{\cdot\cdot\cdot}$	ppm.	—	0,01	0,008	0,008	0,015
$Al^{\cdot\cdot\cdot}$	ppm.	—	0,07	0,02	0,06	0,09
NH_4	ppm.	—	0,16	0,08	0,00	0,08
NO_2'	ppm.	—	0,00	0,00	0,00	0,00
NO_3'	ppm.	—	0,094	0,101	0,07	0,128
Cl'	ppm.	—	1,99	2,41	1,99	2,41
F'	ppm.	—	0,048	0,134	0,046	0,044
P_2O_5	ppm.	—	0,12	0,00	0,17	0,18
diss. SiO_2	ppm.	—	9,7	10,5	4,4	6,4
Alk. (HCO_3')	mval.	0,4	0,4	0,25	0,08	0,28
free CO_2	ppm.	—	66	35,2	—	—
aggr. CO_2	ppm.	—	4,2	3,6	—	—

TABLE 3

Upper course regions of Kalu Ganga, Kelani Ganga and Gin Ganga (500–800 meter)

Station		*FC* 5	*FC* 6	*FC* 8	*FC* 14	*FC* 35	*FC* 36
altitude		700	700	500	800	650	625
μS/cm. (conduct.)		19,0	22,5	33,2	14,6	36,0	18,7
p_H (field)		5,5	5,5	5,8	5,5	6,0	6,0
p_H (electrom.)		5,54	6,20	6,30	6,54	6,80	7,7
$KMnO_4$—consump.		9,1	6,3	6,3	20,5	12,6	10,7
Humic acids	ppm.	0,189	0,378	0,302	0,245	0,000	0,000
hardness° German		0,17	0,28	0,42	0,25	0,82	0,24
CaO	ppm.	0,34	1,34	1,90	1,12	5,15	1,68
MgO	ppm.	1,01	1,05	1,56	0,99	2,16	0,50
$Ca^{\cdot\cdot}$	ppm.	0,24	0,96	1,37	0,81	3,71	1,21
$Mg^{\cdot\cdot}$	ppm.	0,61	0,63	0,94	0,59	1,30	0,30
$Na^{\cdot}$	ppm.	1,35	2,14	3,46	1,20	2,60	2,10
$K^{\cdot}$	ppm.	0,78	0,75	1,29	0,40	0,40	0,60
$Fe^{\cdot\cdot}Fe^{\cdot\cdot\cdot}$	ppm.	0,02	0,02	0,01	0,005	0,000	0,005
$Al^{\cdot\cdot\cdot}$	ppm.	0,09	0,06	0,16	0,02	0,04	0,05
$NH_4^{\cdot}$	ppm.	0,15	0,20	0,20	0,21	0,03	0,03
NO_2'	ppm.	0,00	0,00	0,00	0,00	—	—
NO_3'	ppm.	0,175	0,054	0,054	0,94	0,048	0,037
Cl'	ppm.	2,56	3,27	3,83	1,60	1,99	1,70
F'	ppm.	0,042	0,04	0,043	0,05	0,051	0,043
P_2O_5	ppm.	0,08	0,10	0,10	0,12	0,16	0,18
diss. SiO_2	ppm.	5,6	8,2	13,0	7,4	12,3	11,2
Alk. (HCO_3')	mval.	0,08	0,12	0,3	0,14	0,4	0,14
free CO_2	ppm.	—	—	—	11,4	—	—
aggr. CO_2	ppm.	—	—	—	4,5	—	—

TABLE 4

Mountain region of Maskeliya and Nuwara Eliya (Sources of Kelani Ganga and Mahaweli Ganga)

Station		*FC* 16	*FC* 17	*FC* 18	*FC* 19	*FC* 20	*FC* 20A
Altitude (m)		1300	1850	1500	1500	1200	1000
μS/cm. (conduct.)		25	8,85	10,2	23,8	11,0	20,1
p_H (field)		5,7	5,4	5,8	6,1	6,3	6,7
p_H (electrom.)		6,10	5,68	5,95	6,35	6,36	6,13
$KMnO_4$—consump.	ppm.	19,8	28,8	19,5	26,2	9,2	—
Humic acids	ppm.	0,227	1,021	1,096	0,302	0,113	0,340
hardness° German		0,4	0,08	0,13	0,45	0,15	0,4
CaO	ppm.	2,58	0,34	0,78	2,69	0,9	1,6
MgO	ppm.	1,02	0,43	0,37	1,30	0,44	1,7
$Ca^{\cdot\cdot}$	ppm.	1,86	0,24	0,56	1,94	0,65	1,15
$Mg^{\cdot\cdot}$	ppm.	0,61	0,26	0,22	0,78	0,26	1,02
$Na^{\cdot}$	ppm.	1,2	0,6	0,5	1,3	0,7	1,4
$K^{\cdot}$	ppm.	0,9	0,2	0,2	0,7	0,15	1,2
$Fe^{\cdot\cdot}Fe^{\cdot\cdot\cdot}$	ppm.	0,02	0,015	0,015	0,006	0,005	0,8
$Al^{\cdot\cdot\cdot}$	ppm.	0,08	0,1	0,09	0,06	0,03	0,03
NH_4.	ppm.	0,1	0,25	0,25	0,00	0,15	0,17
NO_2'	ppm.	0,01	0,00	0,00	0,00	0,00	0,02
NO_3'	ppm.	0,283	0,048	0,045	0,754	0,042	0,075
Cl'	ppm.	2,84	0,14	1,42	2,84	1,7	2,69
F'	ppm.	0,16	0,057	0,038	0,038	0,035	0,08

P_2O_5	ppm.	0,17	0,00	0,02	0,10	0,00	0,08
diss. SiO_2	ppm.	4,44	2,61	1,98	4,44	3,15	3,12
Alk. (NCO_3')	mval.	0,12	0,05	0,05	0,07	0,15	0,20
free CO_2	ppm.	39,2	55	55	44	44	132
aggr. CO_2	ppm.	5,8	5,5	5,0	6,4	3,6	3,3

TABLE 4 (*continued*)

Station		*Adam's Peak*	*FC* 23	*FC* 21
Altitude (m)		2200	1200	2000
μS/cm. (conduct.)		22,2	36,5	26,3
p_H (field)		6,0	6,0	5,8
p_H (electrom.)		6,10	6,35	6,90
$KMnO_4$—consump.		—	23,4	17,3
Humic acids	ppm.	0,491	0,076	0,065
hardness° German		0,3	0,6	0,65
CaO	ppm.	2,52	4,14	2,69
MgO	ppm.	0,50	1,34	2,74
$Ca^{\cdot\cdot}$	ppm.	1,81	2,98	1,94
$Mg^{\cdot\cdot}$	ppm.	0,30	0,80	1,64
$Na^{\cdot}$	ppm.	1,9	1,9	2,8
$K^{\cdot}$	ppm.	0,6	1,4	0,4
$Fe^{\cdot\cdot}Fe^{\cdot\cdot\cdot}$	ppm.	0,01	0,005	0,017
$Al^{\cdot\cdot\cdot}$	ppm.	0,02	0,02	0,07
NH_4.	ppm.	0,23	0,04	0,20
NO_2'	ppm.	0.00	0.01	0,00
NO_3'	ppm.	0,263	0,128	0,067
Cl'	ppm.	2,84	4,97	2,55
F'	ppm.	0,051	0,044	0,048
P_2O_5	ppm.	0,01	0,07	0,02
diss. SiO_2	ppm.	2,52	7,20	13,3
Alk. (NCO_3')	mval.	0,38	0,40	0,25
free CO_2	ppm.	—	—	55
aggr. CO_2	ppm.	—	—	4,4

TABLE 5

Region of the steep descent to the south of Horton's Plains
(400–700 meter)

Station		*FC* 24	*FC* 25	*FC* 26	*FC* 29	*FC* 30
altitude (m)		650	700	700	500	400
μS/cm. (conduct.)		23	34	45,6	34	89,2
p_H (field)		5,8	6,0	6,5	6,0	7,0
p_H (electrom.)		6,65	7,10	7,00	6,7	7,2
$KMnO_4$—consump.		11,2	15,5	12,0	19,0	10,7
Humic acids	ppm.	0,227	0,076	0,038	0,000	0,1512
hardness° German		0,55	1,0	1,3	0,8	2,35
CaO	ppm.	2,35	4,70	6,83	3,70	15,57
MgO	ppm.	2,27	3,82	4,44	3,10	5,71
$Ca^{\cdot\cdot}$	ppm.	1,79	3,38	4,91	2,66	11,21
$Mg^{\cdot\cdot}$	ppm.	1,36	2,29	2,66	1,86	3,43
$Na^{\cdot}$	ppm.	1,4	1,4	2,6	1,2	6,2

$K^{\cdot}$	ppm.	0,3	0,35	1,1	0,6	1,8
$Fe^{\cdot\cdot}Fe^{\cdot\cdot\cdot}$	ppm.	0,004	0,008	0,008	0,000	0,000
$Al^{\cdot\cdot\cdot}$	ppm.	0,094	0,100	0,023	0,03	0,05
$NH_4^{\cdot}$	ppm.	0,03	0,03	0,00	0,08	0,04
NO_2'	ppm.	∠0,01	0,00	0,00	0,00	∠0,01
NO_3'	ppm.	0,123	0,071	0,101	0,35	0,054
Cl'	ppm.	1,42	1,42	1,84	2,41	4,82
F'	ppm.	0,444	0,04	0,053	0,06	0,112
P_2O_5	ppm.	0,17	0,14	0,10	0,06	0,17
diss. SiO_2	ppm.	9,0	11,0	13,0	11,5	24,8
Alk. (HCO_3')	mval.	0,3	0,45	0,53	0,3	0,97
free CO_2	ppm.	44	22	20	—	—
aggr. CO_2	ppm.	3,2	2,2	2,4	—	—

TABLE 6

Water systems outside of the wet region (to SE and N of the mountains)

Station		*FC* 27	*FC* 28	*FC* 32
altitude (m)		150	200	50
μS/cm. (conduct.)		295	360	605
p_H (field)		7,4	7,4	—
p_H (electrom.)		7,70	8,30	7,25
$KMnO_4$—consump.		13,3	17,7	27,4
total Humic acids	ppm.	0,454	0,076	1,814
total hardness° German		9,2	11,6	12,9
CaO	ppm.	52,00	59,36	50,90
MgO	ppm.	28,87	40,75	56,00
$Ca^{\cdot\cdot}$	ppm.	37,44	42,74	36,74
$Mg^{\cdot\cdot}$	ppm.	17,32	24,45	33,60
$Na^{\cdot}$	ppm.	17,30	28,00	73,80
$K^{\cdot}$	ppm.	3,10	2,50	6,00
$Fe^{\cdot\cdot}Fe^{\cdot\cdot\cdot}$	ppm.	0,008	0,009	0,008
$Al^{\cdot\cdot\cdot}$	ppm.	0,01	0,03	0,08
$NH_4^{\cdot}$	ppm.	0,02	0,08	0,22
NO_2'	ppm.	0,005	0,00	—
NO_3'	ppm.	0,108	0,101	0,081
Cl'	ppm.	7,10	2,55	145,6
F'	ppm.	0,27	0,55	0,18
P_2O_5	ppm.	0,11	0,08	0,18
diss. SiO_2	ppm.	28,8	54,8	15,0
Alk. (HCO_3')	mval.	3,55	4,7	1,6
free CO_2	ppm.	198	110	—
aggr. CO_2	ppm.	0,5	0,0	—

TABLE 1

Hydrochemical Characteristic of the different regions. (Compare Tables 1-6)

Kelani-Ganga, 0–20m. above sea-level

Station		*FC* 33B *Estuary*	*FC* 33A *Colombo/ Kelaniya*	*FC* 38 *Hanwella*
distance from the coast (km.)		0,5	3	15
conductivity uS/cm.		288	42,6	27
pH		6,4	6,5	6,4
$KMnO_4$—consump.		13,3	28,4	22,1
hardness° German		1,83	0,51	0,36
$Ca^{\cdot\cdot}$	ppm.	1,15	2,09	1,81
$Mg^{\cdot\cdot}$	ppm.	5,81	2,96	0,48
$Al^{\cdot\cdot\cdot}$	ppm.	0,09	0,04	0,03
$Na^{\cdot}$	ppm.	1,00	4,80	2,00
$K^{\cdot}$	ppm.	3,50	5,00	0,95
$Cl^{\cdot}$	ppm	85,2	7,38	2,84
SiO_2	ppm.	6,95	3,00	3,50
HCO_3'	mval.	0,44	0,36	0,08
Humus acids	ppm.	0,151	0,038	0,000
NH_4	ppm.	0,04	0,015	0,01
P_2O_5	ppm.	0,08	0,04	0,02

The rivers of the wet region have very soft water even near their flow outs; the chemical details being similar to those of the upper courses. In the lower course of the river (Colombo-region) electrolytes increase ($Mg^{\cdot\cdot}$, $Al^{\cdot\cdot\cdot}$, Cl', SiO_2, P_2O_5) as well as Humus acids, which had been absent at Hanwella. Slight increase of NH_4 and of $KMnO_4$-demand may be the result from certain influences of sewage flowing out near Colombo. It is interesting to note that the maximum content of $Ca^{\cdot\cdot}$, $Na^{\cdot}$, $K^{\cdot}$, Fe-total, F' is found about 3 miles from the sea (near Colombo) and these componestn decrease in the estuary. The estuary-water has a high conductivity, has much $Mg^{\cdot\cdot}$ and Cl' (influence of sea-water—tides). The content of SiO_2 is nearly equal to that of water from Beira lake and the slight increase of Humus acids may come from certain influences of the vegetation and swamp banks. Stagnating water such as that of Beira lake contains much Ca, Mg and especially Na and Cl.

3.2. **River-systems of the wet region** (first and second peneplain)

TABLES 2 / 3

Kalu-Ganga (upper + middle course), **Kelani-Ganga** (middle course)

Gin-Ganga (only upper course)

Kalu-Ganga

Station	*first peneplain* FC 12	*second peneplain* FC 13	FC 15	FC 14
altitude (m.)	30	80	100	800
conductivity µS/cm.	46,2	41,5	25,5	14,6
p_H (field)	6,0	6,0	5,9	5,5
hardness° German	1,4	1,15	0,5	0,25
$Ca^{\cdot\cdot}$ ppm.	6,00	4,89	1,69	0,81
$Mg^{\cdot\cdot}$ ppm.	2,42	2,21	1,15	0,59
$Na^{\cdot}$ ppm.	—	1,90	2,30	1,20
$K^{\cdot}$ ppm.	—	0,80	0,80	0,40
$Al^{\cdot\cdot\cdot}$ ppm.	—	0,07	0,02	0,02
NH_4 ppm.	—	0,16	0,08	0,21
NO_3, ppm.	—	0,09	0,10	0,09
Cl' ppm.	—	1,99	2,41	1,60
SiO_3 ppm.	—	9,7	10,7	7,4
HCO_3' mval.	0,4	0,4	0,25	0,14
$KMnO_4$—consump.	—	19,1	17,6	20,5
Humus acids ppm.	—	0,567	0,186	0,245

The increase of conductivity, hardness ($Ca^{\cdot\cdot}$, $Mg^{\cdot\cdot}$) and Alkalinity is nearly linear with the falling altitude of the river. It is also similar with $Al^{\cdot\cdot\cdot}$ and SiO_2 (with one maximum amount in FC 15—a tributary running through plantations); as also with the Humus acids. Chloride is slightly increasing, like Sodium, with a maximum in FC 15, (perhaps like iron FC 13 0.01, upstream 0,005-0,008). But, upstream you find more ammonium, while nitrate-contents are stabilized.

Kelani-Ganga : in the region of Kitulgala (tributaries), second peneplain :

Stations	FC 37	FC 34	FC 35	FC 36
altitude (m.)	64	80	650	625
conductivity µS/cm.	33,4	18,2	36	18,7
p_H (field)	6,0	5,9	6,0	6,6
hardness° German	0,71	0,21	0,82	0,24
$Ca^{\cdot\cdot}$ ppm.	3,23	0,73	3,71	1,21
$Mg^{\cdot\cdot}$ ppm.	1,10	0,48	1,30	0,30
$Na^{\cdot}$ ppm.	1,80	2,00	2,60	2,10
$K^{\cdot}$ ppm.	1,10	0,35	0,40	0,60
$Al^{\cdot\cdot\cdot}$ ppm.	0,09	0,06	0,04	0,05
$NH_4^{\cdot}$ ppm.	0,08	0,00	0,03	0,03
NO_3' ppm.	0,13	0,07	0,05	0,04
Cl' ppm.	2,41	1,99	1,99	1,70
SiO_2 ppm.	6,4	4,4	12,3	11,2
NCO_3' mval.	0,28	0,08	0,4	0,14
Humus acids ppm.	0,113	0,151	0,000	0,000
$KMnO_4$—consump.	15,8	18,3	12,6	10,7

The nearly linear increase of conductivity in the direction of the flow of water from the mountain region to the lowland is interrupted by visibly greater increase of electrolytes in the region of Kitulgala (compare with Table 3a). This effect may be because of the influence of crystalline limestones on the hydrochemistry of some tributaries (FC 35, FC 36) which contain more silicates and more calcium (only FC 35). The content of SiO_2 seems to be parallel to the dissolved calcium (magnesium), these facts are especially seen in the dry zone (FC 27, 28) and may also be because of the higher amount of HCO'_3 and CO_2 (FC 35) in forest areas. Humic acids are absent in these tributaries, as well as organic matter which occur in very little quantities.

TABLE 3 a

Kelani-Ganga : details of the whole river system

		FC 33B Estuary	*FC 38 Hanwella*	*FC 37 Kitulgala*	*FC 20A Barrage*	*FC 20 Maskeliya*	*FC 17 Mountain Forest*
altitude (m)		0–1	20	64	1000	1200	1850
T°C (12°°)		—	26,5	25,4	20	19	17
conductivity		288	27	33,4	20,1	11	8,8
p_H (field)		6,4	6,4	6,0	6,7	6,3	5,4
hardness°		1,83	0,36	0,71	0,4	0,15	0,08
Ca··	ppm	1,15	1,81	3,23	1,15	0,65	0,24
Mg··	ppm	5,81	0,48	1,10	1,02	0,26	0,26
Na·	ppm	1,00	2,00	1,80	1,40	0,70	0,60
K·	ppm	3,50	0,95	1,10	1,20	0,15	0,20
Fe··Fe···	ppm	0,04	0,014	0,015	0,80	0,005	0,015
Al···	ppm	0,09	0,03	0,09	0,03	0,03	0,10
NH_4.	ppm	0,04	0,01	0,08	0,17	0,15	0,25
NO_3,	ppm	0,21	0,16	0,13	0,08	0,04	0,05
Cl'	ppm	85,2	2,84	2,41	2,69	1,70	1,14
F'	ppm	0,049	0,057	0,044	0,08	0,035	0,057
P_2O_5	ppm	0,08	0,02	0,18	0,08	0,00	0,00
SiO_2	ppm	6,95	3,50	6,40	3,12	3,15	2,61
HCO_3'	mval	0,44	0,08	0,28	0,20	0,15	0,05
Humus acids		0,151	0,000	0,113	0,340	0,113	1,021
$KMnO_4$ consump.		13,3	22,1	15,8	—	9,2	28,8

Region of Sinharaja-Forest (Table 3)

Stations		*FC 5 affluents of Gin-Ganga*	*FC 6 affluents of Gin-Ganga*	*FC 8 affluents of Nilwala-Ganga*
altitude (m)		700	700	500
conductivity		19	22,5	33,2
p_H (field)		5,5	5,5	5,8
hardness°		0,17	0,28	0,42
Ca··	ppm	0,24	0,96	1,37
Mg··	ppm	0,61	0,63	0,94
Na·	ppm	1,35	2,14	3,46
K·	ppm	0,78	0,75	1,29
Al···	ppm	0,°9	0,06	0,16
NH_4·	ppm	0,15	0,20	0,20
NO_3'	ppm	0,17	0,°5	0,05
Cl'	ppm	2,56	3,27	3,87
SiO_2	ppm	5,6	8,2	13,0
HCO_3'	mval	0,08	0,12	0,3
Humus acids	ppm	0,189	0,378	0,302
$KMnO_4$—consump.		9,1	6,3	6,3

Both affluents of the Gin-Ganga are somewhat similar to the rivers of the mountainous tea-region (FC 19, 16, 23), but contain more SiO_2, more NH_4 (like the spring-rivers from the mountain rain-forest). The amount of Humus acids is nearly the same. These affluents are characteristic of the water coming from the wet rain forest (Sinharaja) ; they are acidic, have a higher content of ammonium and Humus-acids, with an extremely low content of dissolved calcium, but with more magnesium, sodium, potassium and silicate than the highland-rivers. This may be due to the influence of more active soil filtration and vegetation.

The affluent of Nilwala-Ganga has a higher conductivity and may be sligher influenced by crystalline limestones ; which have a high percentage of dissolved silicate.

Central mountain region (Maskeliya, Nuwara Eliya, ad Table 4) third and fourth peneplain

Maskeliya-Barrage (altitude 1,000m), Sampling stations up to 1850m and 2200m (Adam's peak).

Highland series (granite, charnockite quartzite).

Main river is the Kelani-Ganga (FC 16, 17, 18, 19, 20, 20A, 23).

(1) Affluents coming directly from the mountin rain forest head water region on the high-plateau in the south-east (uphill are the tea-plantations of Upcot).

(2) From Maskeliya

Influence of cascades on water chemistry :

Region of tea-plantations High-plateau (mountain rain-forest)

Station		*FC* 18 *cascade*	*FC* 17
altitude (m)		1500	1850
conductivity		10,2	8,85
p_H (field)		5,8	5,4
hardness°		0,13	0,08
$Ca^{\cdot\cdot}$	ppm.	0,56	0,24
$Mg^{\cdot\cdot}$	ppm.	0,22	0,26
$Na^{\cdot}$	ppm.	0,5	0,6
$K^{\cdot}$	ppm.	0,2	0,2
$Al^{\cdot\cdot}$	ppm.	0,09	0,1
$NH_4^{\cdot}$	ppm.	0,25	0,25
NO_3'	ppm.	0,04	0,05
Cl'	ppm.	1,42	1,14
F'	ppm.	0,038	0,057
P_2O_5	ppm.	0,02	0,00
SiO_2	ppm.	1,98	2,61
HCO_3'	mval.	0,05	0,05
aggress. CO_2	ppm.	5,0	5,5
Humus acids	ppm.	1,096	1,021
$KMnO_4$—consump.		19,5	28,8

Downstream are found the great cascades—conductivity, hardness (more Ca··), Cl' slightly increase, as well as p_H. Free carbondioxide content appears to be not influenced by the enormous cascades (55 mg up and down), but aggressive CO_2 decreases, as also Mg, Na, Al, NO_3, F, and SiO_2. This may be due to the direct influence of rain water drained by the rocks. *The content of Humus-acids and ammonium is remarkably high* !

Affluents from tea-plantations (Maskeliya-Hatton)

Station		*FC 19*	*FC 16*	*FC 23*
altitude (m)		1500	1300	1200
conductivity		23,8	25	36,5
p_H (field)		6,1	5,7	6,0
hardness° German		0,45	0,4	0,6
Ca··	ppm	1,94	1,86	2,98
Mg··	ppm	0,78	0,61	0,80
Na·	ppm	1,3	1,2	1,9
K·	ppm	0,7	0,9	1,4
Al···	ppm	0,06	0,08	0,02
NH_4·	ppm	0,00	0,1	0,04
NO_3'	ppm	0,75	0,28	0,13
Cl'	ppm	2,84	2,84	4,97
F'	ppm	0,038	0,16	0,044
P_2O_5	ppm	0,10	0,17	0,07
SiO_2	ppm	4,44	4,44	7,20
HCO_3'	ppm	0,07	0,12	0,40
aggress. CO_2	ppm	6,4	5,8	—
Humus acids	ppm	0,302	0,227	0,076
$KMnO_4$—consump.		26,2	19,8	23,4

FC 19 and FC 16 are little streams in the Maskeliya-Upcot region, both flowing into the Barrage. FC 23 is a somewhat polluted river near Hatton, with the same destination.

All these water samples have a greater conductivity and hardness than the sources from the mountain rain forest. Acidity is approximatively equal to that of the reddish soil pH (5, 5-6, 0) which is supposed to be ideal for tea-cultivation. The amount of aggressive CO_2 is very high for such surface-waters (highest measured).

The content of Humus-acids is comparatively low, although remarkable. The erosion of soil is extremely intensive because of the high rainfall all over the year and due to the cutting down of the natural forest. In cases where the slopes are steep, all the soil has been washed down. Because of this reason, the washing of sandy material and earth after rainfall may be higher than in former times, and this may have a possible influence on the absence of gastropods, beside the high calceous aggressivity.

Affluents coming directly from the northern flank of the Adam's Peak

		FC 20	*Fountain Spout on Adam's Peak*	(20*A*) *flow out of the Maskeliya-Barrage (compare point* 1,2)
altitude (m.)		1200	2200	1000
conductivity		11	22,2	20,1
PH (field)		6,3	6,0	6,1
hardness°		0,15	0,3	0,4
Ca··	ppm.	0,65	1,81	1,15
Mg...	ppm.	0,26	0,30	1,02
Na·	ppm.	0,7	1,9	1,4
K·	ppm.	0,15	0,6	1,2
Fe ···	ppm.	0,005	0,01	0,8
Al ···	ppm.	0,03	0,02	0,03
NH_4·	ppm.	0,15	0,23	0,17
NO_3'	ppm.	0,004	0,26	0,07 NO_2 0,02
Cl'	ppm.	1,70	2,84	2,69
F'	ppm.	0,035	0,051	0,08
P_2O_5	ppm.	0,00	0,01	0,08
SiO_2	ppm.	3,15	2,52	3,12
HCO_3'	mval.	0,15	0,38	0,20
Humus acids	ppm.	0,227	0,491	0,340
$KMnO_4$—	consump.	9,2	—	—

The main affluent coming from the Adam's Peak massif (FC 20, Maskeliya Dola) has a very similar hydrochemistry to the affluents coming directly from the mountain-forest-head water region, (FC 17), except that there is much smaller content of Humus acids, NH_4, and organic matter. In comparison with the headwater-region on the other side of the mountain (South-flank, Ratnapura-region), that is with the upper reaches of the Kalu-Ganga (FC 14) flowing through rain forest, the Kalu-Ganga springs are more acidic (5,5), have a higher conductivity, and have slightly more Ca, Mg, Na, K, NH_4, more silicates and organic matter, while Humus acids are more less the same.

The water sample from the top region of Adam's Peak has a higher conductivity, more Ca, Na ,NH_4, NO_3, Cl and Humus acids, but less silicate than the main river running downwards.

The flow out of the Barrage is a mixture of all tributaries and is most similar to the characteristic tea-region rivers (FC 16, 19) but its water contains a lot of dissolved iron (0, 8-2, 3 mg./1).

This Iron orignates from decompositional processes under total consumption of oxygen (aerobic and anaerobic rotting of organic matter, relicts of vegetation, washed down earth) and is soluted out from the stone as Fe (II).

Region of Nuwara Eliya, Affluents of Mahaweli-Ganga (less rain than at Maskeliya)

Station		*FC 21*
altitude (m)		2000
conductivity		26,3
PH (field)		5,8
hardness° German		0,65
$Ca^{\cdot\cdot}$	ppm.	1,94
$Mg^{\cdot\cdot}$	ppm.	1,64
$Na^{\cdot}$	ppm.	2,8
$K^{\cdot}$	ppm.	0,4
Fe ...	ppm.	0,02
Al ...	ppm.	0,07
$NH_4^{\cdot}$	ppm.	0,20
NO_3'	ppm.	0,07
Cl'	ppm.	2,55
F'	ppm.	0,048
P_2O_5	ppm.	0,02
SiO_2	ppm.	13,3
HCO_3'	mval	0,25
aggress. CO_2	ppm.	4,4
Humus acids	ppm.	0,605
$KMnO_4$—consmp.		17,3

The frequent occurence of acquatic gastropods make this stream rather remarkable, because those were missing in the whole of Maskeliya-district. Conductivity, hardness, are not extremely low, while NH_4 and Humus-acids are reminiscent of the typical tea-plantation region. However the amount of SiO_2 increases.

This region has less extremes of rainfall unlike Maskeliya. (grassland (patana) is the typical vegetation on the mountain region).

Water systems outside of the wet region (below 2000 mm. annual rainfall) (see Table 6).

These rivers and streams are influenced by limestone formations. Conductivity and hardness, when compared with water samples from the running waters from the wet region are, extremely high, but you also find higher conductivity and hardness in stagnating bodies in the wet region (Table 1, Beira lake near Colombo).

In particular, the dissolved content of silicates is notable, highest in FC 28 (Wetakei-Ela a small torrent near Wellawaya running through dense forest, typical dry primary forest of the Chloroxylon ecosystem, BRINCK 1971). This torrent has a calcarous sinter, with much silicates, on the stones. The amount of free CO_2 in these rivers in the Southeast seems to be very high, possibly as a result of the presence of intensive humus-layers in the rather brown soil. BRINCK mentions the effect of acid gneisses in the Southeast with a deficiency of ferromagnesian minerals on the development of non-calcic brown soils. The high contents of SiO_2 originate presumably from these gneisses, while the crystalline limestones have only a local influence.

FC 32 (region of Polonnaruwa) seems to be influenced by agricultural drainage-waters, the content of Na, K, NH_4, Humus acids and chloride is extraordinarily high.

Limestone—aggressivity of highland rivers

(Content of aggressive CO_2 in ppm CO_2, °German hardness)

Studied in samples FC 13-28

4,4 CO_2 aggr.
0,65°
2000 m.

5,5 CO_2 aggr,
0,08°
1850 m.

5,0 CO_2
0,13°
1500 m.

6,4 CO_2 aggr.
0,45°
1500 m.

5,8 CO_2 aggr.
0,4°
1,300m.

3,6 CO_2 aggr.
0,15°
1,200m.

3,3 CO_2 aggr.
0,4°
1,000m.

(gastropods missing) ....

(FC 16) (FC 17) (FC 18) (FC 19) (FC 20) (FC 20A) FC 21

4,5 CO_2 aggr.
0,25°
800m.

2,2
1,0°
700m.

2,4 CO_2 aggr.
1,3°
700m.

3,2 CO_2
0,55°
650m.

0,0 CO_2 aggr.
11,6°
200m.

0,5 CO_2
9,2°
150m.

3,6 CO_2 aggr.
0,5°
100m.

4,2 CO_2 aggr.
1,15°
80m.

FC 13 FC 14 FC 15 FC 24 FC 25 FC 26 FC 27 FC 28

Most aggressive Carbondioxide is therefore found in the samples FC 16, 17, 18, 19. The critical amount of aggressive CO_2 to the existence of acquatic gastropods (*Paludomus*, etc.) seems to be 4-5 ppm. aggr. CO_2 in conjunction with extreme small contents of Ca and Mg (Maskeliya-region). The rivers near Nuwara Eliya (FC 21) are colonized again by gastropods, although they are situated at a higher altitude (altitude 2,000m.). This water has more Mg, more Na, and more SiO_2 than those of Maskeliya.

Humus acids

The brown-yellowish colour of natural waters, originating from the decomposition of organic matter (Lignin), are signified as Humus acids. For the exact differentiation into components ; Fulvin-, Humin-, Hymatomelanin acids—see BLACK (1963).

		Tota Humus acids	*Humus acid A ppm.*
FC 5	Sinharaja-Forest	0,1890	0,1456
FC 6	Do.	0,3024	0,2184
FC 8	Do.	0,3780	0,2912
FC 13	Kalu Ganga	0,5670	0,1456
FC 17	Mountain Forest	1,0206	0,8736
FC 18	Do.	1,0962	0,8008
FC 19	Mountain Forest (Adam's Peak)	0,3024	0,2184
FC 21	Mountain Forest (Nuwara Eliya)	0,6048	0,5096
FC 27	Dry forest (Buttala)	0,4536	—
FC 28	Dry forest (Wellawaya)	0,0756	—
FC 32	Dry forest (Polonnaruwa)	1,8144	1,0192

A comparative measurement of water from a Barrage in a granite area of northern Austria (2,3° German hardness) showed the presence of 0,8695 ppm. humic acids. The buffer-capacity of this water is much higher, the p_H being about 6,8.

DISCUSSION

The more extreme the ecological situation is for the formation of biotopes themselves and for their life, as especially in the tropics, the more precisely will the biotopes be characterized (SIOLI, et al 1969). The greater part of the Brazilian Amazon produces waters which are very poor in dissolved inorganic components, like slightly contaminated distilled water, and they are somewhat similar to the Ceylonese highland-waters. They are more acidic (p_H about 4,5)—than the Ceylonese (wet region) running waters—as they lack the common bicarbonate-buffer system. The archean massifs in the north and south produce such water with low p_H, still poorer and more acid are waters in the pliocene-pleistocene areas. In all the Amazonian geological zones there are spots of bleached sands (podsols) covered with a special vegetation type, which produce " balck water ", while clear water comes from yellowish brown-loams (latosols), with high forest cover, (SIOLI 1968). SIOLI mentioned too about the small quantities of substances that are added continuously by the rain (nitrogen, even phosphate) and which are not stored in thickening layers of humus but are simultaneously eliminated from the ecosystem of the landscape in the same amounts by the great amount of rain (Rainfall in the Amazonian region is about 1,500-3,500 mm.). This means that the rain forest of Amazonia is growing actually on top of the soil and not from it, and that the soil cover serves more as a substratum for the mechanical fixation of the forest trees than as a source for their nutrition.

Black waters—yellowish to reddish brown—due to their great content of dissolved or colloidal humic substances, have a higher permanganate consumption than the other waters, and a certain amount of aluminium (mean value 0, 016 ppm. in the Rio Negro) from which element the white and clear waters are free. The iron content is highei, nitrogen is only present as ammonium, p_H is very acid.

The presence of aluminium in black water and its absence in clear water is explanied by different ways of chemical decomposition of rocks in podsols and tropical brown latosols (SIOLI et al 1969).

With regard to the content of aluminium, the Ceylonese highland-streams and rivers of the wet region are not completely " clear water ". This fact is confirmed by the high amount of dissolved ammonium and humic substance also mentioned by GEISLER (1967), who presumed this type of water as " eau humique partiellement neutralisee " (BERG 1961). Beginning stages of some regional influences (wet mountain forest, for instance) of special vegetation somewhat similar to the " black water producing species " may have some importance, but the dilution by rain-water seems to be extremely high. In effect all Ceylonese highland-rivers look very clear.

A great influence on the hydrochemistry of any region is the enrichment of the water with carbondioxide while it is dripping through the soil. This process is determined by climate, geology, geomorphology, soil and vegetation and is obvious especially in tropical islands which have different types of climate in comparatively small areas. These effects have been studied on ultrabasic stone (Periodotite) in the south-west Pacific with an extremely high content of dissolved magnesium (WENINGER 1967). The drier part of the island had much more dissolved electrolytes than the wet part, where the rivers also were very short.

GEISLER mentions about the high quantity of dissolved iron in the rivers of the second peneplain in the south-west of Ceylon (max. 0,23 ppm. total iron). The highland-rivers however contain as a mean only 0,02 ppm. total iron, except at the flow out of the Maskeliya-barrage (08-2,3ppm. total iron) where all life was absent. Calcium and magnesium are least dissolved in water and the procentual proportion Ca/mg. is like those of granite. In most samples calcium pre-dominates, magnesium, while sodium itself can sometimes predominate calcium. Due to the acidic character of the gneisses and granites the content of fluoride is not extremely low.

The algal production of the highland rivers seems to be very small, perhaps limited by the small content of nutrients, while the population of insect-larvae was rather dense (HORA 1936).

Interesting to note is the complete absence of aquatic gastropods in most of the highland streams except the Nuwara Eliyaregion. This may be due to the high aggressivity of water (CO_2) against the calcarous shells of molluscs, and also may be due to the enormous erosion, drift of gravel and earth in the rivers, which have been highly increased by cutting down of all timber for tea-plantations.

SUMMARY

The morphology, climate, geology and geochemistry of Ceylon is briefly described. The separation into a wet zone—the South-west and greater part of the central highland—and a dry zone with two very dry parts in the South-east and in the North-west, is obvious and has great influence on the hydrochemistry of the island. Geology is very homogenous (precambian crystalline series) and some jurassic and miocene limestones (only in the North).

The sampling stations (November, December 1970) are described. The investigations concentrated on studying the highland regions near Maskeliya, the Kelani-Ganga, downstream upto the flow out, the Kalu-Ganga near Ratnapura, the region of Sinharaja-forest and the cascades near Belihuloya, besides some stations outside the wet region. Nearly all running water of the wet zone is characterized by the extreme poverty of dissolved inorganic substances and by the slightly acid nature. Sodium predominates calcium sometimes, while calcium predominates magnesium equivalent to the composition of the rocks. With the increasing altitude of the sampling stations, the poorness in dissoved minerals increases. Minimal conductivity measured has been 8,8 uS/cm. in the affluents coming from the headwater-region of the mountain rain-forest, with high contents of humic substances and ammonium.

The content of aggressive CO_2 was measured and there seem to be connections between the absence of aquatic gastropods in the highland region and the aggressivity of water against their calcarous shells.

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