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NATURE OF THE DISSOLVED LOAD OF THE KRISHNA RIVER BASIN, INDIA

R. RAMESH and V. SUBRAMANIAN*

School of Environmental Sciences, Jawaharlal Nehru University, New Delhi-110 067 (India)

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ABSTRACT

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River water samples were collected four times during a three year period (1981–84) at sixteen stations in the entire region of Krishna River and its major tributaries. On the basis of our analytical results, the discharge weighted average chemical composition of the Krishna River has been computed and compared to major river systems of the world. The total dissolved transport of Krishna to the Bay of Bengal is estimated to be 10.4 × 10^6 t yr^{-1} which accounts 4% of the chemical load of the Indian subcontinent. The average annual chemical erosion rate at the river mouth is estimated to be 41 t km^{-2} yr^{-1}. The fluxes of individual dissolved species of Krishna River water to the Bay of Bengal are in the following order: HCO_3 > SO_4 > Na > Cl > dissolved Si > Mg > K > F > PO_4.

The observed chemical data of Krishna River water have been used to predict theorectically the mineral assemblages in the carbonate and in alumino-silicate systems and compared to observed mineralogical composition of suspended sediments.

INTRODUCTION

A river basin represents the most active component in the hydrological cycle. In material transport, the river plays a very important role. Nearly 90% of the continental weathering products is transported to the oceans by rivers (Garrels et al., 1975). Therefore, the chemistry of river waters and the flux of elements transported by them to the oceans are central to our understanding of exogenic cycles of elements. In a river basin, diverse factors influence the hydrological activities—weathering of drainage basin rocks, erosion of weathered products, fractionation of individual metals between water, sediments and biota etc., vary within a basin from the catchment to the river mouth areas. There are thus temporal and spatial variations in these geochemical parameters.

Geochemical studies on surface waters have been a subject of study by

* Present address: Department of Geological Sciences, McGill University, Montreal, Que. H3A 2A7 (Canada)

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TABLE 1

Some hydrological characteristics of the Krishna River Basin

Location no.	River	Site	Drainage area (km^2)	Discharge (10^6 m^3)*				
				Feb.	April	June	August	Annual
1	Krishna	Kolhar	5462	41	51	340	1542	4502
2	Krishna	Sangam	55150	82	17	941	6401	20960
3	Krishna	Sangam	55150	82	17	941	6401	20960
4	Krishna	Raichur	136618	39	27	1525	8883	34026
5	Krishna	Kurnool	210500	206	94	1538	11412	87718
6	Krishna	Srisailam	206041	268	146	893	11365	50345
7	Krishna	Vijayawada	251360	197	92	160	7508	29962
8	Krishna	Rapalle	251360	197	92	160	7508	29962
9	Krishna	Nagayalanka	251360	197	92	160	7508	29962
10	Krishna	Nagayalanka	251360	197	92	160	7508	29962
11	Gataprabha	Bagalkot	8610	33	7	121	1046	3259
12	Malaprabha	Sangam	11400	42	12	114	248	1752
13	Bhima	Yadgir	69863	69	19	351	2671	11496
14	Tungabhadra	Hampi	38018	165	224	75	3032	8448
15	Tungabhadra	Mantralayam	60630	180	182	154	2967	9215
16	Tungabhadra	Kurnool	67180	22	42	132	2073	6922

* Mean discharge for 10 years (1971–81) calculated from Central Water Commission data.

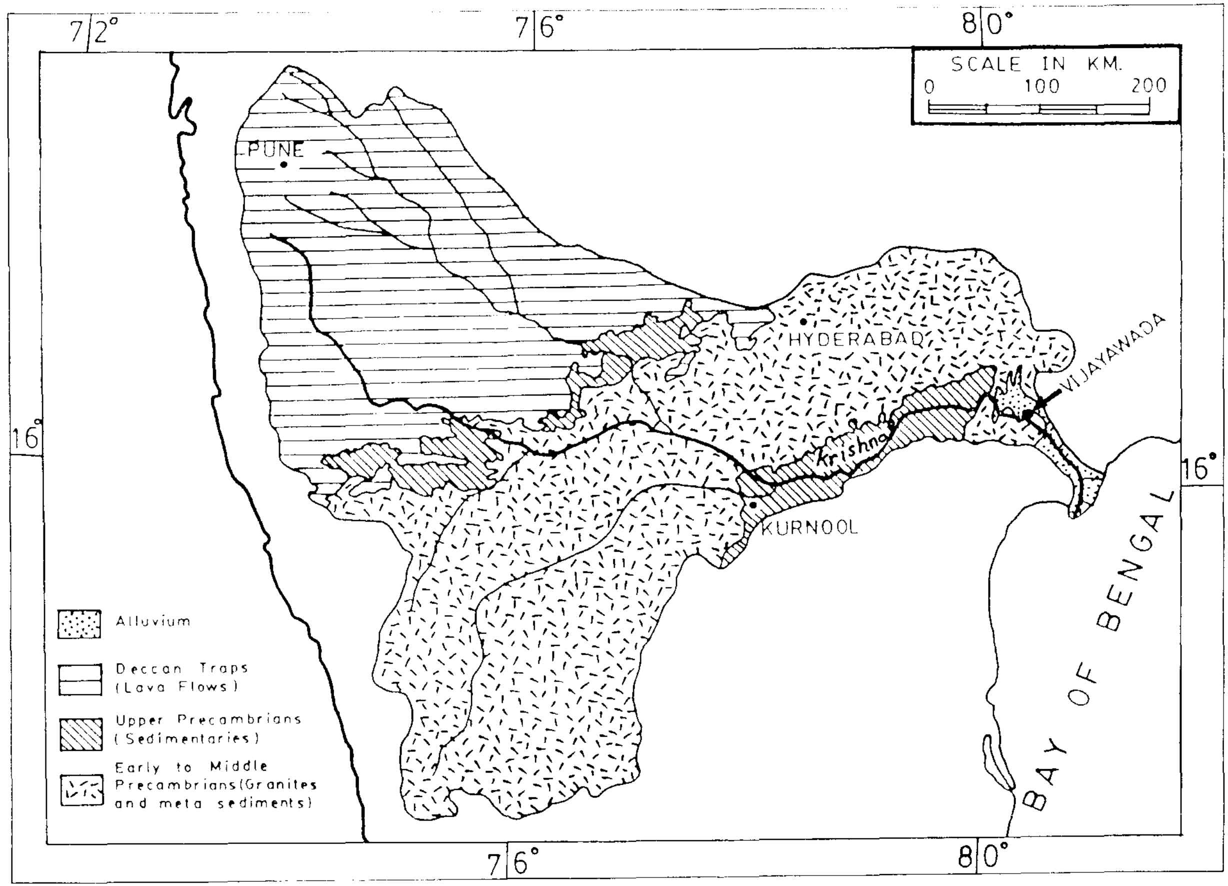


Fig. 1. Geological map of the Krishna River Basin.

several groups of workers (Livingstone, 1963; Meybeck, 1976). More recently, Hu Ming-hui et al. (1982) reported on the major element chemistry of large Chinese rivers and Brahmaputra. Subramanian (1983) and Sarin and Krishnaswami (1984) reported on Ganges, Brahmaputra and other large Indian rivers. Nevertheless, the chemical composition of the medium-size Asian rivers is still poorly documented except for a few works (e.g., Subramanian, 1983; Biksham, 1985; Subramanian et al., 1985). In India, the Krishna, Godavari, Mahanadi, Narmada, Tapti and Cauvery river basins are middle size of the order of (1 to 3) $\times$ 10^5 km^2 basin area and these rivers are presumed to contribute for a great part to the continental dissolved and particulate input to the ocean (Meybeck, 1976). There is practically no information on the surface waters of Krishna River. Hence this paper deals with the chemistry and fluxes of dissolved phases in the Krishna River Basin.

KRISHNA RIVER BASIN

The basin covers an area of 258,945 km^2, representing about 10% of the area of continental India. Table 1 summarises some of the important hydrological characteristics of the Krishna River Basin. Throughout the river basin, maximum discharge is reported to occur in the month of August. A generalised geological map with major tributaries is shown in Fig. 1. Originating from the

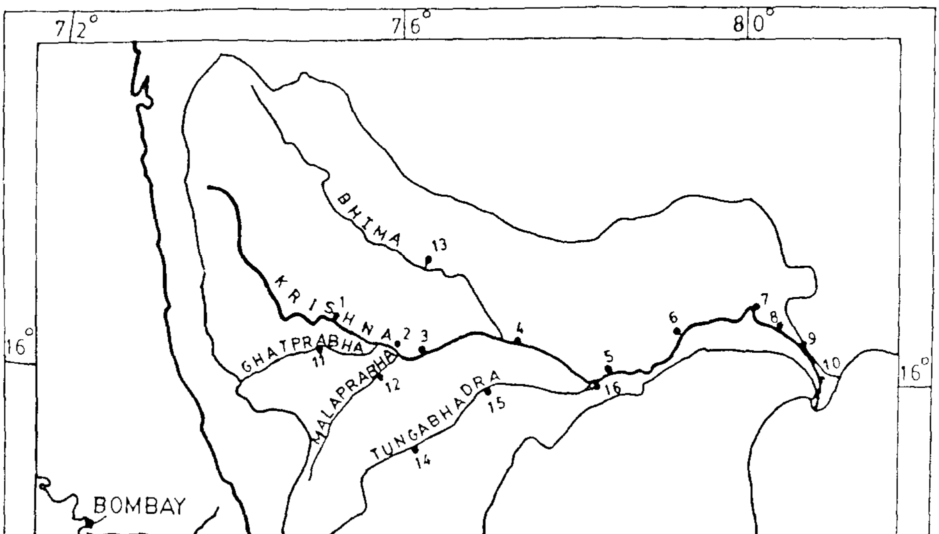


Fig. 2. Basin map of the Krishna River with sampling locations (dots with nos. 1–16).

TABLE 2

Discharge weighted average chemical composition ($mg\,l^{-1}$) of the Krishna and its tributaries

Sample no.[1]	pH	Cond.[2]	HCO_3	Cl	PO_4	SO_4	F	H_4SiO_4	Ca	Mg	Na	K	TDS
1	7.28	287.27	132.95	31.46	0.10	30.90	0.23	27.45	21.37	6.88	15.53	1.66	268.23
2	7.28	248.12	173.33	24.87	0.10	25.05	0.20	20.51	20.68	4.93	13.76	1.41	284.55
3	7.71	439.33	174.17	53.39	0.05	30.59	0.29	21.47	30.43	9.84	34.33	2.14	356.38
4	7.81	500.53	195.74	46.55	0.06	104.71	0.30	26.77	30.08	10.37	34.27	2.45	450.94
5	7.57	358.77	188.76	32.23	0.05	41.71	0.58	28.32	32.28	7.66	24.67	1.54	357.20
6	7.63	314.29	172.31	25.96	0.09	32.03	0.39	24.63	31.87	6.86	24.28	2.20	320.16
7	7.52	433.02	150.29	39.79	0.10	46.24	0.41	23.99	35.71	9.08	39.01	3.00	347.12
8	7.71	426.80	164.83	42.65	0.10	78.50	0.31	24.17	37.34	9.25	40.95	3.07	400.71
9	7.80	444.63	158.15	44.96	0.06	76.82	0.32	23.15	36.73	9.38	40.18	3.88	393.27
10	7.81	544.69	151.63	81.33	0.06	75.09	0.21	23.09	36.49	11.48	52.07	3.77	434.98
11	7.44	228.11	165.57	17.61	0.10	52.50	0.21	18.33	21.77	4.68	11.21	1.27	292.98
12	7.78	585.34	186.17	80.88	0.08	44.38	0.32	32.65	27.71	13.58	46.25	3.03	434.74
13	7.71	475.61	299.57	11.10	0.09	56.94	0.31	38.68	23.09	11.87	44.01	3.39	514.21
14	7.33	139.77	138.26	16.25	0.09	11.49	0.39	18.36	16.74	3.72	11.62	1.28	218.57
15	7.40	322.79	196.35	32.64	0.09	36.98	0.52	15.03	28.74	5.48	30.26	2.39	348.82
16	7.46	276.79	198.95	24.84	0.06	38.40	0.61	17.61	32.38	4.91	23.73	1.35	341.28

[1] Sample numbers correspond to locations in Fig. 2 and in Table 1, columns 2 and 3.
[2] Cond. = conductivity in ($\mu S\,cm^{-1}$).

Western Ghats, the main river flows through nearly 80% on Archaean and younger crystalline rocks while the remaining 20% flows on Tertiary Deccan Traps (basaltic) and recent sediments. The Tungabhadra tributary flows through 70% Archaean and 30% Precambrian crystalline rock terrain while the Bhima tributary flows through 80% Deccan Trap terrain.

The climate in most of the basin is semi-arid with an arid zone in the centre. Rainfall in this basin is mainly due to the southwest monsoon. Except for a narrow strip along the Western Ghats and a small portion at the lower end, the Krishna Basin has an average annual rainfall of less than 500 mm of which 75% occurs during the southwest monsoon.

METHODOLOGY

One-litre water samples were collected in polythene bottles from various parts of the river basin including major tributaries in four times (April 1982; February 1984; June 1984; August 1984) to broadly cover seasonal variations. Figure 2 shows the location of the sampling stations. Field measurement of pH and alkalinity, preservation of samples for laboratory work and water analysis (major cations and anions) were based on standard techniques (Subramanian, 1979). Mean discharge data for these locations for the years 1971–81 were taken from unpublished reports of the Central Water Commission, Government of India.

RESULTS AND DISCUSSION

Major-ion chemistry

Table 2 summarises the average chemical composition of the Krishna River and its tributaries. The average values were calculated from the data obtained in four seasons. Table 3 summarises the average chemical composition of river waters of India. Also given for comparison are the average compositions of Chinese, Zarie, Amazon and World average.

The average chemical composition of the Krishna River water shows erratic downstream variations. In general, minima and maxima in the downstream profile are related to the diluting and concentrating effects of tributary inflows, with respectively low and high Total Dissolved Solids (TDS) contents and their mixing volumes. The high abundance of dissolved silica and the low (Ca + Mg):(Na + K) ratios suggest that the contribution of major ions by silicate weathering is more significant in Krishna River water. Like other major world rivers, the Krishna River is alkaline. The high percentage of HCO_3 in the river water is consistant, with the drainage lithology. For example, the Bhima shows very high HCO_3 values. This is possible because of the Deccan Traps that underlie a major portion of the Bhima ranges in composition from mafic to felsic rocks and these rocks are easily susceptible to chemical weathering. Seasonal data, not given in this paper, indicate a high content of HCO_3 in the monsoon season. Subramanian (1983) reported that during the monsoon period, atmospherically regulated pCO_2–water reactions, may further enhance the carbonate alkalinity.

TABLE 3

Average chemical composition (mg l^{-1}) of Indian, Chinese and World rivers

River	Discharge (10^6 m^3 yr^{-1})	Alkalinity	Cl	SO_4	SiO_2	Ca	Mg	Na	K	TDS	Reference
Krishna	29962	178	38	49	24	29	8.1	30	2.4	360	Present study
Cauvery	20950	53.3	18	39	8.4	15.4	16	30	2.6	172	Subramanian et al. (1985)
Godavari	92300	105	17	8	10	22	5	12	3.0	181	Biksham (1985)
Ganges	493400	100	5.6	9.4	3.1	40.4	6	8.7	3.9	178	Abbas and Subramanian (1984)
Brahmaputra	510450	37.5	15	9.5	6.7	29	7.4	12	2.5	148	Subramanian (1983)
Indus	207800	64	9.2	15	5.3	26.8	0.7	1.3	2.1	122	Subramanian (1983)
Narmada	40705	225	20	5	9	14	20	27	2.0	322	Subramanian (1983)
Tapti	17982	150	65	0.6	16	19	22	47.5	3.0	322	Subramanian (1983)
Indian rivers	1700000	74	15	13	7	30	7	12	3.0	159	Subramanian (1983)
Chinese rivers	1777000	113	7	14	3	33	5.5	5	1.5	181	Hu Ming-hui et al. (1982)
Zarie	1230000	11.2	2.9	3	9.8	2.4	1.3	1.7	1.1	33	Meybeck (1979)
Amazon	5500000	22.5	3.9	3	11.2	6.5	1.0	3.1	1.0	52	Gibbs (1972)
World	31400000	62.2	3.7	9.2	12.4	16	4	4.4	1.5	115	Sarin and Krishnaswami (1984)

TABLE 4

Average annual fluxes of dissolved species

Sample no.	Data*	HCO_3	Cl	PO_4	SO_4	F	H_4SiO_4	Ca	Mg	Na	K	TDS
Krishna River Basin												
1	a	598.51	141.62	0.44	139.12	1.02	123.58	96.21	30.98	69.90	7.48	1207.49
	b	109.58	25.93	0.08	25.47	0.19	22.63	17.61	5.67	12.80	1.37	221.07
	c	49.57	11.73	0.04	11.52	0.08	10.23	7.97	2.57	5.79	0.62	100.00
2	a	3632.39	521.34	2.00	525.15	4.27	429.83	433.47	103.25	288.48	29.52	5964.15
	b	65.87	9.45	0.04	9.52	0.08	7.79	7.86	1.87	5.23	0.54	108.14
	c	60.91	8.74	0.03	8.81	0.07	7.21	7.27	1.73	4.84	0.49	100.00
3	a	3650.64	1119.05	1.09	641.13	6.07	449.99	637.89	206.31	719.60	44.90	7469.74
	b	66.19	20.29	0.02	11.63	0.11	8.16	11.57	3.74	13.05	0.81	135.44
	c	48.87	14.98	0.01	8.58	0.08	6.02	8.54	2.76	9.63	0.60	100.00
4	a	6660.17	1583.76	2.14	3562.73	10.28	910.78	1023.56	353.01	1166.04	83.47	15343.66
	b	48.75	11.59	0.02	26.08	0.08	6.67	7.49	2.58	8.54	0.61	112.31
	c	43.41	10.32	0.01	23.22	0.07	5.94	6.67	2.30	7.60	0.54	100.00
5	a	16557.51	2827.42	4.12	3658.99	50.79	2484.24	2831.16	672.20	2164.28	135.03	31332.82
	b	78.66	13.43	0.02	17.38	0.24	11.60	13.45	3.19	10.28	0.64	148.85
	c	52.84	9.02	0.01	11.68	0.16	7.93	9.04	2.15	6.91	0.43	100.00
6	a	3675.11	1306.91	4.46	1612.72	19.75	1240.20	1604.28	345.54	1222.26	110.59	16118.67
	b	42.10	6.34	0.02	7.83	0.10	6.02	7.79	1.68	5.93	0.54	78.23
	c	53.82	8.11	0.03	10.01	0.12	7.69	9.95	2.14	7.58	0.69	100.00
7	a	4503.03	1192.20	2.92	1385.35	12.15	718.67	1069.84	271.99	1168.68	89.89	10400.39
	b	17.91	4.74	0.01	5.51	0.05	2.86	4.26	1.08	4.65	0.36	41.38
	c	43.30	11.46	0.03	13.32	0.12	6.91	10.29	2.62	11.24	0.86	100.00
8	a	4938.50	1277.91	2.93	2351.94	9.42	724.21	1118.71	277.20	1227.01	91.96	12005.95
	b	19.65	5.08	0.01	9.36	0.04	2.88	4.45	1.10	4.88	0.37	47.76
	c	41.13	10.64	0.02	19.59	0.08	6.03	9.32	2.31	10.22	0.77	100.00
9	a	4738.37	1347.03	1.65	2301.62	9.51	693.71	1100.48	280.95	1203.81	116.31	11783.03
	b	18.85	5.36	0.01	9.16	0.04	2.76	4.38	1.12	4.79	0.46	46.88
	c	40.21	11.43	0.01	19.53	0.08	5.89	9.34	2.38	10.22	0.99	100.00

10	a	4543.07	2436.92	1.68	2249.82	6.42	691.74	1093.44	344.00	1560.17	113.06	13032.96
	b	18.07	9.69	0.01	8.95	0.03	2.75	4.35	1.37	6.21	0.45	51.85
	c	34.06	18.70	0.01	17.26	0.05	5.31	8.39	2.64	11.97	0.87	100.00
Tributaires of the Krishna												
11	a	539.58	57.38	0.32	171.08	0.68	59.75	70.96	15.26	36.55	4.15	954.79
	b	62.67	6.66	0.04	19.87	0.08	6.94	8.24	1.77	4.24	0.48	110.89
	c	56.51	6.01	0.03	17.92	0.07	6.26	7.43	1.60	3.83	0.43	100.00
12	a	326.08	141.66	0.14	77.72	0.56	57.19	48.54	23.78	81.01	5.31	761.45
	b	28.60	12.43	0.01	6.82	0.05	5.02	4.26	2.09	7.11	0.47	66.79
	c	42.82	18.60	0.02	10.21	0.07	7.51	6.37	3.12	10.64	0.70	100.00
13	a	3443.71	127.58	0.99	654.58	3.59	444.65	265.42	136.50	505.92	38.91	5911.07
	b	49.29	1.83	0.01	9.37	0.05	6.36	3.80	1.95	7.24	0.56	84.61
	c	58.26	2.16	0.02	11.07	0.06	7.52	4.49	2.31	8.56	0.66	100.00
14	a	1167.97	137.25	0.78	97.05	3.29	155.10	141.41	31.42	98.12	10.83	1846.48
	b	30.72	3.61	0.02	2.55	0.09	4.08	3.72	0.83	2.58	0.28	48.57
	c	63.25	7.43	0.04	5.26	0.18	8.40	7.66	1.70	5.31	0.59	100.00
15	a	1809.44	300.75	0.80	340.74	4.76	138.48	264.83	50.53	278.81	22.05	3214.43
	b	29.84	4.96	0.01	5.62	0.08	2.28	4.37	0.83	4.60	0.36	53.02
	c	56.29	9.36	0.02	10.60	0.15	4.31	8.24	1.57	8.67	0.69	100.00
16	a	1377.19	171.94	0.42	265.83	4.24	121.90	224.16	33.99	164.29	9.31	2362.51
	b	20.50	2.56	0.01	3.96	0.06	1.81	3.34	0.51	2.45	0.14	35.17
	c	58.29	7.28	0.02	11.25	0.18	5.16	9.49	1.44	6.95	0.39	100.00

* Data: a = dissolved flux (1000 t yr^{-1}); b = rate of chemical erosion (t km^{-2} yr^{-1}); c = percentage of each element.
Sample numbers correspond to locations in Fig. 2 and in Table 1, colums 2 and 3.

Ca varies from 4 to 9% of the TDS whereas Mg varies from 3 to 6%. The Krishna River water probably derives Ca from dissolution of lime rocks, plagioclase and other ferromagnesium minerals and Mg from hydrolysis of olivine bearing rocks in the source area. Na and Cl values are not balanced here because of differing contributions from lithology and precipitation. The high concentration of Na may be related to the breakdown of feldspars, Cl from chlorite-bearing rocks and atmospheric precipitation. There is an increase in Cl and Na content at the downstream station (no.10 ref. Fig. 1, Table 2). This reflects the importance of marine contribution. K remains almost constant throughout the basin, suggesting conservative behaviour in river systems (Garrels and Mackenzie, 1971). The Tungabhadra, major tributary of the Krishna, drains mostly on crystalline rocks like granite and hence the water shows high F values (0.4 to 0.6 ppm). The general acceptable limit of fluoride in drinking water has been fixed at 0.5 ppm (WHO). Deshmukh (1974) studied the F content in rivers of Peninsular India and reported that rivers flowing over granites recorded up to 3.5 ppm.

The average chemical composition of Krishna River water (Table 3) shows that HCO_3 is the most abundant anion and Na is the most abundant cation. High HCO_3 content indicates that intense chemical weathering takes place throughout the basin (Garrels and Mackenzie, 1971). High content of Na confirms the well-known fact that Na is a very mobile ion which is rapidly evacuated by running water. The Krishna River is characterized by a very high content of total dissolved solids, over double that of the Ganges, Godavari and Chinese rivers (Table 3). All the peninsular rivers except the Cauvery show very high alkalinity. In addition to weathering, the extent of mixing with groundwater rich in HCO_3 provides a major source for high alkalinity in peninsular rivers. From Table 3 we can observe two types of relationship i.e., low discharge–high TDS for the peninsular rivers and high discharge–low TDS for the Himalayan rivers. In spite of their large discharge, the Amazon and Zarie show very low concentrations of all constituents. Thus, compared to Himalayan and world rivers, peninsular rivers, particularly the Krishna, are chemically more active river basins.

Fluxes

The dissolved fluxes at various stations of the basin (Table 4) were calculated using discharge weighted average TDS values (Table 2) and mean of ten years annual discharge (Table 1). Table 4 also gives the annual flux of individual elements for the Krishna River Basin and its tributaries, together with erosion rates and percentage of contribution of each element to the total load. Table 5 summarises the annual flux of individual ions for the Krishna and other large Indian rivers. Also shown are the published annual fluxes for the Chinese, Zarie, Amazon and the World average.

TABLE 5

Average chemical flux (10^6 t) in Indian, Chinese and World rivers

River	Alkalinity	Cl	SO_4	SiO_2	Ca	Mg	Na	K	Total annual flux	Average fluxes calculated from
Krishna	5.33	1.14	1.47	0.72	0.87	0.24	0.9	0.07	10.79	Present study
Cauvery	1.17	0.38	0.82	0.18	0.32	0.34	0.63	0.05	3.6	Subramanian et al (1985)
Godavari	9.69	1.57	0.74	0.92	2.03	0.46	1.1	0.28	16.71	Biksham (1985)
Ganges	49.34	8.39	4.64	1.53	19.98	2.96	4.29	1.92	87.83	Abbas and Subramanian (1984)
Brahmaputra	19.14	7.66	4.85	3.42	14.80	3.78	6.13	1.28	75.55	Subramanian (1983)
Indus	13.30	1.91	3.12	1.10	5.57	0.15	0.27	0.44	25.35	Subramanian (1983)
Narmada	9.16	0.81	0.20	0.37	0.57	0.81	1.10	0.08	13.11	Subramanian (1983)
Tapti	2.70	1.17	0.01	0.29	0.34	0.40	8.54	5.39	5.79	Subramanian (1983)
Indian rivers	125.80	25.50	22.10	11.90	51.00	11.90	20.40	5.10	270.30	Subramanian (1983)
Chinese rivers	200.80	12.44	24.88	5.33	58.64	9.77	15.79	2.67	321.64	Hu Ming-hui et al. (1982)
Zarie	13.78	3.56	3.69	12.05	2.95	1.60	2.09	1.35	40.59	Meybeck (1979)
Amazon	123.75	21.45	16.50	61.60	35.75	5.50	17.05	5.50	286.00	Gibbs (1972)
World	1953.08	119.88	288.88	389.36	502.40	125.60	138.16	47.10	3611.00	Sarin and Krishnaswami (1984)

At Vijayawada (mouth of the river) the Krishna River delivers annually 10.4×10^6 t of dissolved load to the Bay of Bengal. This accounts for 4% of the chemical load of the Indian subcontinent. All the Indian rivers together contribute 7% of the chemical load to the world oceans and the Krishna contributes 0.3% of world's dissolved transport. The approximate contributions of each dissolved species by the Krishna River to the Bay of Bengal are as follows: HCO_3, 43% (9% as inorganic carbon); Cl, 11%; SO_4, 13% (5% as sulphur); dissolved Si, 7%; Na, 11%; Ca, 10%; Mg, 3%; K, 1%; PO_4, 0.03% (0.01% as phosphorus) and F, 0.12%. Within the basin the various fluxes and rates indicate a lack of uniformity, primarily due to different subbasin geology, elevation and various degrees of human impact.

A comparison of the average chemical flux (Table 5) shows that Indian rivers carry 270×10^6 t of solutes annually, which is almost equal to the load transported by the Amazon despite the considerably greater discharge of the latter. In spite of diverse geology, elevation, discharge and area of the individual drainage basin, the chemical fluxes of the Indian rivers vary within a limited range from a low value of 3.6×10^6 t for Cauvery to a high value of 87.83×10^6 t for the Ganges. The Chinese rivers, which have approximately the same discharge as the Indian rivers, carry a larger solute load primarily due to higher mean concentration of alkalinity. Even though the chemical load of the world's big rivers like the Amazon is several times higher than that of the Krishna, the erosion rates are higher in the Krishna. Thus, the size of the basin or the river discharge has no effect on the rate of chemical erosion.

Water-mineral equilibria in carbonate and silicate weathering

The mineral stability can be predicted by the application of thermodynamic concepts to chemical equilibria of the water (Kramer, 1967). The principle behind such an application; water derives its composition from the parent rock in the weathering region; the suspended sediments owe their mineralogical composition partly to the parent rock and partly to the chemical reaction of rock and water. When such reactions reach chemical equilibrium certain mineral assemblages principally clay minerals will coexist in the sediment phase provided the chemistry of water does not change. For example, the weathering of albite can be written as:

$$2\,H_2CO_3 + 9\,H_2O + 2\,NaAlSi_3O_8$$

$$\rightarrow Al_2Si_2O_5(OH)_4 + 4\,H_4SiO_4 + 2\,Na^+ + 2\,HCO_3^-$$

At constant values of CO_2, Na and HCO_3 the albite–kaolinite assemblage can be considered in stable equilibrium with the water. Thus, by studying the water chemistry, stable mineral assemblages can be theoretically predicted. In the present study an attempt has been made to apply similar concepts to the Krishna River water.

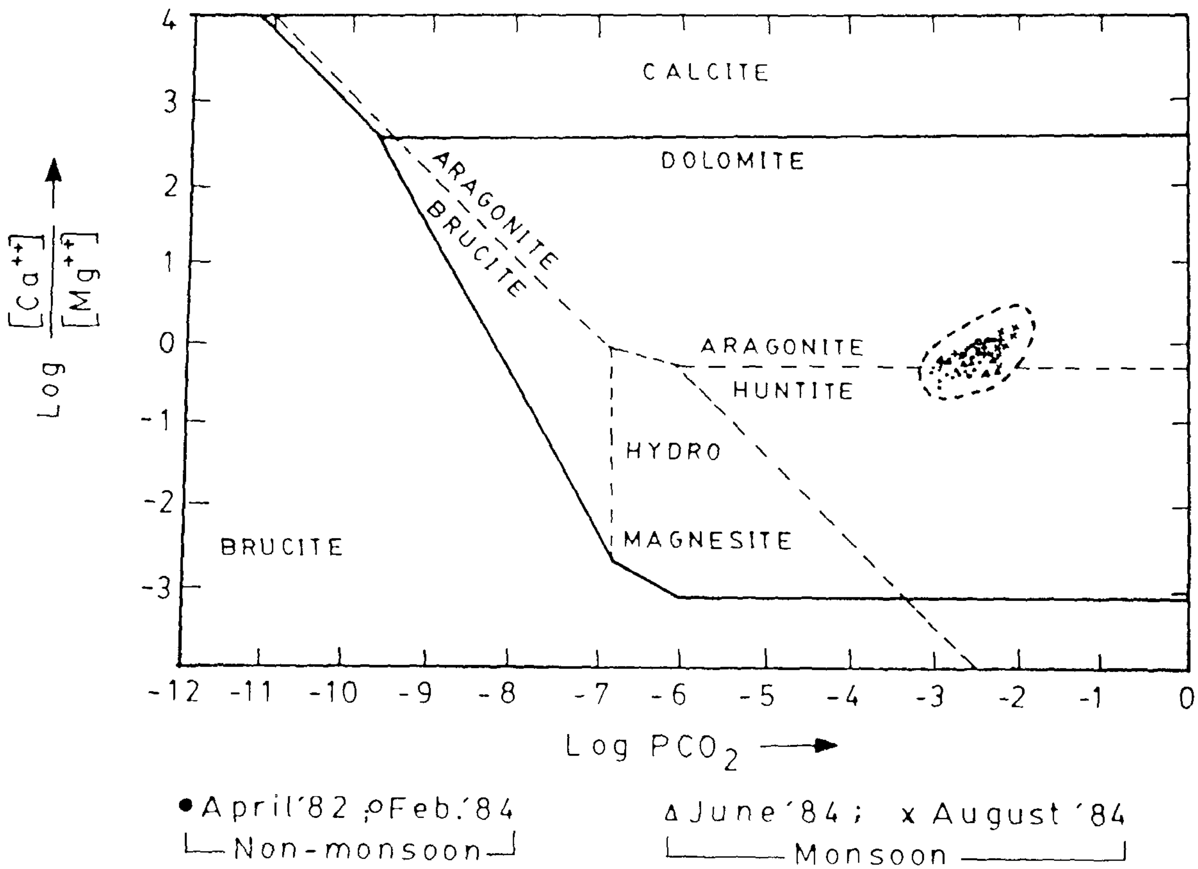
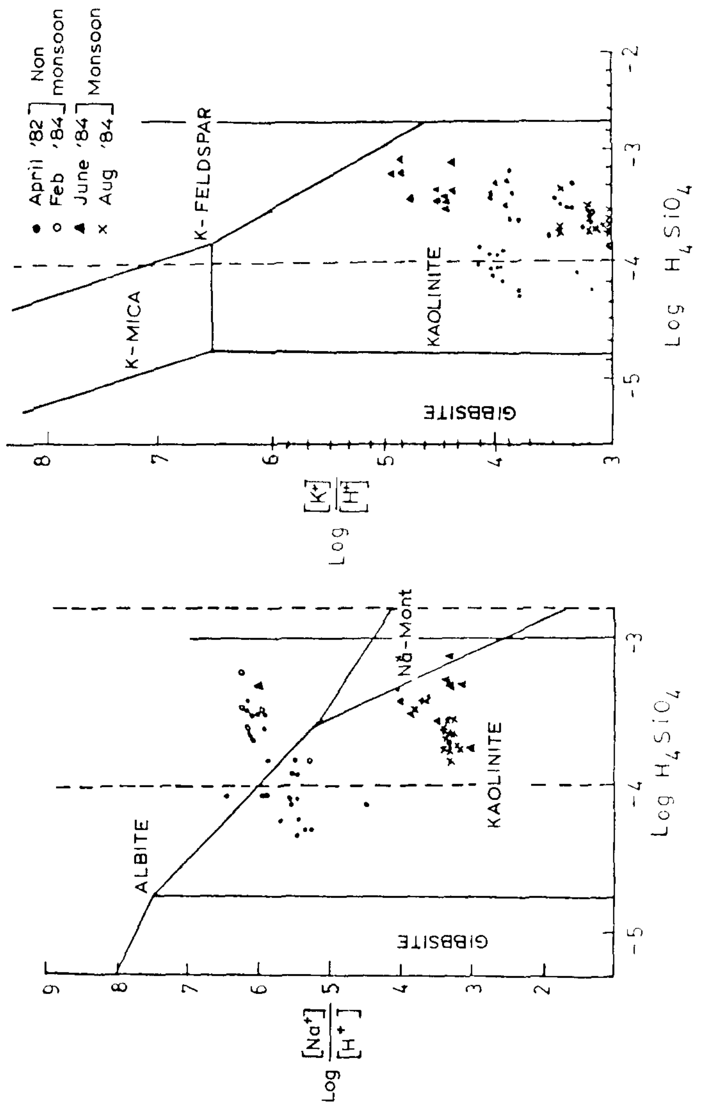


Fig. 3. Water composition in a carbonate system.


• April '82
○ Feb '84
Non monsoon
▲ June '84
× Aug '84
Monsoon
K-FELDSPAR
K-MICA
KAOLINITE
GIBBSITE
Log [K+]/[H+]
Log H_4SiO_4
ALBITE
Na-Mont
KAOLINITE
GIBBSITE
Log [Na+]/[H+]
Log H_4SiO_4

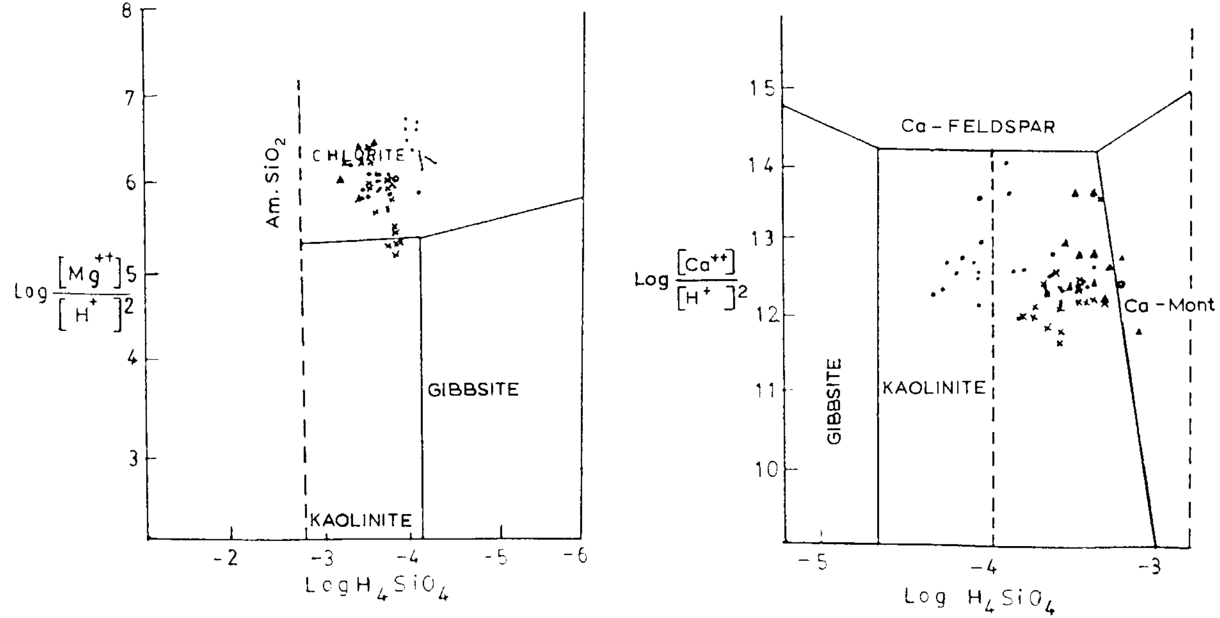


Fig. 4. Water composition in a silicate system.

The phase diagram (Fig. 3) for the carbonate system shows that dolomite is the expected mineral to be in equilibrium with the water irrespective of the seasons. The X-ray diffraction studies of the suspended sediments, not given in this paper, show a considerable amount of dolomite as well as calcite in all the samples. Dolomite is not precipitated as $CaMg(CO_3)_2$ in natural water but as calcite which in turn is converted to dolomite. In other words the formation of dolomite is not the result of the combination of Ca, Mg and CO_3 ions, but results from the combination of $CaCO_3$ (calcite) with Mg.

Figure 4 shows the behaviour of Krishna River water in the silicate system. The majority of the data points fall in the kaolinite region, except for Mg-alumino silicate system, where all the data points fall in the chlorite region. There is no clear seasonal trend except for the Na-alumino silicate system where the samples collected in February fall in the albite region. Garrels and Mackenzie (1971) and Subramanian (1979) have shown that the plot of river water generally falls in the kaolinite region. X-ray diffraction studies, not shown in this paper, show the presence of kaolinite along with chlorite, montmorillonite and illite.

CONCLUSIONS

Chemical weathering in the Krishna Basin is very significant when compared to other major world rivers. The results indicate that the Krishna waters are nearly twice as saline as those of the Ganges, Godavari and Cauvery. This is partly related to basin geology and partly due to various degrees of human impact like construction of dams, barrages and other anthropogenic effects. In addition, atmospheric contribution provides an important source of certain constituents such as SO_4 in Indian rivers. However, the extent of such influences is not estimated quantitatively.

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