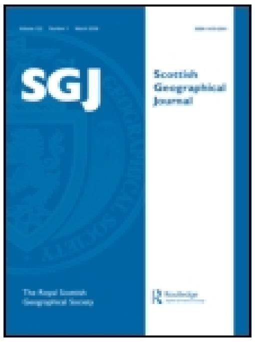

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he lost 1000 men. His party was saved by the arrival of Marno in the *Bordein*, but otherwise was face to face with starvation, and it was even impossible to obtain fuel for the steamers, which were cut off from the shore by impassable swamp. In the spring of 1899 the channel was again closed near this point, while in 1903, as shown in the illustration, there was again a temporary blocking. The channel when clear has only a width of 12 metres, with a depth of 4½ metres, and the course of the stream at all times is extremely tortuous. The effect of blocking is to give rise to a series of lagoons in the marsh, as shown in the figure. The three illustrations indeed indicate the general characteristics of the Bahr-el-Ghazal throughout its length.

THE MINERAL MATTER OF THE SEA.

By Professor R. D. Salisbury, Editor of *The Journal of Geology*.

In his article on "The Height of the Land and the Depth of the Ocean," published in this *Magazine* (vol. iv. pp. 1-41), Sir John Murray gives a series of statistics concerning the height and the cubic contents of the land, and the depth and cubic contents of the ocean. Neither this article nor any other with which the writer is familiar has discussed the amount of mineral matter which sea water contains. The purpose of this note is to direct attention to this point.

The statistics referred to above are grouped in various ways, and bring out numerous instructive facts and relations. Some of the summaries are as follows:—

TABLE I.

Cubic Contents of the Land Areas.

Continent.	Cubic Miles. (By First Estimate.)	Cubic Miles. (By Second Estimate.)	Mean Height. (By First Estimate.)
Europe,	652,750	555,610	939 feet.
Asia,	9,887,050	8,568,450	3,189 "
Africa,	4,246,350	3,658,800	2,021 "
North America,	2,725,500	2,328,550	1,888 "
South America,	2,699,900	2,366,500	2,078 "
Australia,	459,350	396,250	805 "
East Indies,	443,650	380,750	2,144 "
West Indies,	16,150	13,900	816 "
Madagascar,	91,950	80,150	2,199 "
New Zealand,	44,500	38,760	2,134 "
Japan,	38,000	33,010	1,420 "
Formosa,	9,850	8,610	2,341 "
Saghalien,	13,450	12,100	1,667 "
Greenland,	556,350	478,350	3,212 "
Nova Zembla,	14,400	13,650	2,130 "
Spitzbergen,	6,200	5,410	1,057 "
Iceland,	12,200	10,610	1,849 "
Tasmania,	5,600	4,850	1,068 "
	21,923,200	18,954,310	

Mean height—First estimate, 2252 feet.
Second estimate, 1947 feet.

TABLE II.

Cubic Contents of Land, stated in Terms of Altitude.

Height in Feet.	Cubic Miles. (By First Estimate.)	Cubic Miles. (By Second Estimate.)	Percentage. (By First Estimate.)
0 to 600	4,801,000	4,634,200	21·900
600 to 1,500	4,742,250	4,417,650	21·631
1,500 to 3,000	4,679,550	4,211,650	21·345
3,000 to 6,000	4,277,050	3,338,150	19·509
6,000 to 12,000	2,705,300	1,974,410	12·340
12,000 to 18,000	646,350	350,600	2·948
18,000 to 24,000	69,200	21,000	0·316
Over 24,000	2,450	650	0 011
	21,923,150	18,948,310 [1]	100·000
Antarctic Continent,[2] . .	1,520,700	1,314,750	
	23,443,850	20,263,060	

TABLE III.

Areas of the Ocean's Floor at Different Levels.

Fathoms.	Total Square Miles.	Percentages.
Between 0 and 100	10,135,250	7·387
,, 100 and 500	7,380,550	5·379
,, 500 and 1,000	6,475,200	4·719
,, 1,000 and 2,000	29,211,200	21·292
,, 2,000 and 3,000	77,661,650	56·605
,, 3,000 and 4,000	6,190,400	4·512
Over . . 4,000	145,200	0·106
Total, . .	137,199,450	100·000

The percentage of mineral matter in the sea water is usually given at 3·5 per cent. by weight. Assuming its average specific gravity to be 2·5, the 3·5 per cent. by weight becomes 1·4 per cent. by volume. The volume of the sea is estimated by Murray to be 323,722,150 cubic miles,[3] and 1·4 per. cent. of this volume is 4,532,110 cubic miles. This then represents the aggregate volume of mineral matter in the sea if it were precipitated and compacted so as to have an average specific gravity of 2·5. Of this, nearly 78 per cent. by weight is common salt. Assuming the average depth of the sea to be 2076 fathoms (12,456 ft.), as given by Murray,[4] the mineral matter in solution, if precipitated, would cover the ocean bottom to a depth of about 175 feet. Assuming the average depth of the ocean to be 11,500 feet, as given by Murray and Mill,[5] the thickness of the layer would be 161

[1] This figure is given as 18,954,310 in the original table, an error in addition. The figure should, of course, correspond with that of the second column of Table II.

[2] These figures are obtained from the estimated area of the Antarctic Continent and the estimated mean height of the globe; but the Antarctic land is probably higher from the accumulation of snow and ice.

[3] *Op. cit.* p. 39. [4] *Idem.* p. 40. [5] *International Geography*, p. 47.

feet. Other current figures concerning the depth of the ocean give intermediate results.

Assuming the area of the land to be to that of the sea as 28 : 72, the mineral matter of the sea would make a layer about 450 feet thick over the land on the first of the above assumptions, and about 414 feet on the second. It would make a layer about 125 feet thick over the whole earth.

Again, assuming the cubic contents of all the land to be 23,443,850 cubic miles (Table II. above), the mineral matter in solution in the sea, 4,532,110 cubic miles, is equal to nearly one-fifth (19·3 per cent.) of that of the land. Comparing the figures in another way, the mineral matter of the sea is about equal in amount to all of North America (including Newfoundland, the Aleutian Islands, and the Arctic islands except Greenland), Europe (including Great Britain, the Mediterranean and Baltic islands), Australia, the East Indies, the West Indies, Madagascar, New Zealand, Japan, Formosa, Saghalien, Spitzbergen, Iceland, and Tasmania: that is, the amount of mineral matter in solution in the sea water is about equal to the mass of all lands, except Asia, Africa, South America, Antarctica and Greenland[1] (Table I.)

Comparing the amount of mineral matter in solution in the sea with the figures in Table II., it is found that the former falls but little short of that in all lands below 600 feet, or of that in all lands between the altitudes of 600 and 1500 feet, or between 1500 and 3000 feet.

Assuming the average depth of those parts of the sea where the water has a depth of between 0 and 100 fathoms to be 50 fathoms, and the average depth of those parts where the depth of water is between 100 and 500 fathoms to be 300 fathoms, the cubic contents of that part of the sea which has a depth of less than 500 fathoms is about 3,092,000 cubic miles. Assuming the area where the sea water has a depth of between 500 fathoms and $666\frac{2}{3}$ fathoms (4000 feet) to be one-third the area where the depth of the water is between 500 fathoms and 1000 fathoms, and that the average depth of water for the area where the depth is between 500 fathoms and $666\frac{2}{3}$ fathoms is $583\frac{1}{3}$ fathoms (3500 feet), the cubic contents of that part of the sea which lies between these depths is about 1,430,757 cubic miles. This figure, added to the 3,091,965 above, gives about 4,523,000 cubic miles as the approximate volume of the sea, for the area where the depth of the water is less than 4000 feet. This volume is nearly the same as the aggregate volume of mineral matter in the sea water. If these figures are correct, it follows that if the mineral matter of the sea were all precipitated and concentrated about the borders of the land, it would be sufficient to fill the ocean basins up to the present sea-level from the present land borders out to a depth of about 4000 feet: that is, over an area of between 19,000,000 and 20,000,000 square miles. Making allowance for the rise of water which would result from the contraction of the basin if this amount of mineral matter were precipitated in it, the area of land would be increased about 19,000,000 square miles, if all the mineral matter

[1] The area of Greenland, as given by Murray (914,000 square miles), is greatly in excess of the area generally given.

in solution in the sea were precipitated and concentrated about the shores of the lands, filling the ocean basins to the level of the water out to a uniform depth of about 4000 feet. This area, 19,000,000 square miles, is equal to more than one-third the area of all existing land. It is an area nearly equal to that of Asia and Australia: an area nearly equal to North America, South America, Europe, and the East Indies; or to Africa, Europe, Australia, and all islands except the East Indies.

These figures may perhaps give some idea of the amount of mineral matter in solution in the sea, but they give no more than a hint of the importance of the solvent work of water, for most of the substances carried to the sea in solution by rivers are extracted from the water about as rapidly as they are supplied. It is probable, indeed, that the amount of mineral matter which has been extracted from the sea water far exceeds all that remains in solution. This conclusion may be reached either (1) by calculating the volume of rock which has been extracted from the sea water, or (2) by comparing the proportions of the various sorts of mineral matter in sea and in river water.

(1) The rock matter extracted from the sea includes most of the limestone, the gypsum, and the salt, and probably much of the cementing material of all other sorts of sedimentary rocks. Data concerning the thickness of such materials beneath the sea are not available, but their average thickness, for land areas, most of which have been beneath the sea at times, probably far exceeds 250 feet or even 450 feet. Dana suggests that the average thickness of limestone may be 1000 feet.[1] (This figure may have been meant to include dolomite, though it is not so specified.) This figure appears to take no account of the calcium carbonate which forms an important constituent of many shales and some sandstones. Furthermore, much material, such as that of limestone, has been extracted from the sea water and deposited, and then re-dissolved, re-extracted, and re-deposited. Some material, indeed, has probably gone through this cycle repeatedly. Furthermore, these considerations take no account of the deposition of material from solution on the surface of the land, or beneath it, or beneath the surface of the lithosphere under the sea, and these are important parts of the work of ground water.

TABLE IV.

Amount of Mineral Matter in Solution in One Cubic Mile of Sea Water.[2]

Constituents.	Tons.
Chloride of sodium ($NaCl$), ...	117,434,000
Chloride of magnesium ($MgCl_2$), . . .	16,428,000
Sulphate of magnesium ($MgSO_4$), . . .	7,154,000
Sulphate of calcium ($CaSO_4$)	5,437,000
Sulphate of potassium (K_2SO_4), ...	3,723,000
Bromide of magnesium ($MgBr_2$), . . .	328,000
Carbonate of calcium ($CaCO_3$), ...	521,000
For sea water, total dissolved matter,	151,025,000

[1] Dana, *Manual of Geology*, 4th ed., p. 485.

[2] Based on Dittmar's Table, *Challenger Reports*, Physics and Chemistry, vol. i. p. 204.

TABLE V.

Mineral Matter in Solution in One Cubic Mile of Average River Water.[1]

Constituents.	Tons.
Calcium carbonate ($CaCO_3$),	326,710
Magnesium carbonate ($MgCO_3$),	112,870
Calcium phosphate ($Ca_3P_2O_8$),	2,913
Calcium sulphate ($CaSO_4$),	34,361
Sodium sulphate (Na_2SO_4),	31,805
Potassium sulphate (K_2SO_4),	20,358
Sodium nitrate ($NaNO_3$),	26,800
Sodium chloride ($NaCl$),	16,657
Lithium chloride ($LiCl$),	2,462
Ammonium chloride (NH_4Cl),	1,030
Silica (SiO_2),	74,577
Ferric oxide (Fe_2O_3),	13,006
Alumina (Al_2O_3),	14,315
Manganese oxide (Mn_2O_3),	5,703
Organic matter,	79,020
Total dissolved matter,	762,587

(2) By comparing the mineral matter in the sea water with that in average river water (Tables IV. and V.), it is found that calcium carbonate is about twenty times as abundant as sodium chloride in river water, but only $\frac{1}{225}$ as abundant in sea water. If the calcium carbonate which has been taken to the sea in solution by rivers had remained in solution as calcium carbonate in the same proportion that the sodium chloride has remained in the sea water, the figures representing the amount of common salt which the sea contains would seem almost insignificant in comparison. Even if calcium carbonate is changed to calcium sulphate in the sea, as is sometimes thought, the case is not seriously altered, for the amount of calcium sulphate in the sea is but a small fraction of the amount of sodium chloride. In order that the sodium chloride should have attained such predominance, it is necessary to suppose that enormous quantities of the compounds of calcium have been extracted, if the salt of the sea has been derived from the land.

Similarly, the average river water contains about seven times as much magnesium carbonate as sodium chloride, four and a half times as much silica, twice as much calcium sulphate, twice as much sodium sulphate, more potassium sulphate, and more sodium nitrate; yet the combined volume of all these substances in the sea water is but a small fraction of the amount of sodium chloride.

By either of these lines (1) and (2) of approach, we reach the conclusion that the amount of mineral matter which the sea has lost from solution far exceeds that which it has held.

[1] Russell's *Rivers of North America.*