fair size, but the formulae should not be used for very small absolute numbers of births and deaths.

[1] Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 52.

[2] Pearson, K. On a form of spurious correlation which may arise when indices are used in the measurement of organs. *Proc. Roy. Soc.*, **60**, 1897 (489).

THE AVERAGE CHEMICAL COMPOSITION OF IGNEOUS ROCKS

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We have recently completed computations of the average chemical composition of the igneous rocks of various countries, of the continents, and of the earth's crust. These are to be published as a *Professional Paper* of the U. S. Geological Survey, with discussions of the characters of the various averages, of the relative abundance, distribution, association, and evolution of the elements, and other matters. Inasmuch as it is probable that this paper will not appear for a considerable time, it is thought best to publish now the various average compositions arrived at, in order to put before geologists and others some interesting data as to the chemical composition of the earth.

The data used by us were 5,159 chemical analyses of igneous rocks from all over the earth, and published between 1884 and 1913, inclusive. Analyses only of "superior" quality, and of fresh unaltered rocks, were considered. These were taken from a collection of rock analyses made by one of us.[1] In computing the averages of the various countries and the continents the sum total of each constituent was divided by the total number of analyses of rocks from the area dealt with. In the case of the earth average, both in terms of oxides and of elements, the same method was adopted for the major constituents, SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O and H_2O (only water above 110° was considered), while the average for the minor constituents was obtained by taking the mean of the sum total of each divided by the number of analyses (which gives too low a result) and by the number of determinations (which is apt to give too high a result).

In computing the average of the whole crust the relative proportions estimated by one of us[2] some years ago were adopted. The latest estimates of the masses and compositions of the hydrosphere and atmosphere have been used. These relative masses are as follows: Lithosphere 93%; hydrosphere 7%; atmosphere 0.03%.

AVERAGE IGNEOUS ROCKS, UNITED STATES

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	61.41	62.98	57.81	58.54	60.37	60.03	60.09	65.80	61.39	59.97	62.49	60.77
Al_2O_3	15.20	14.74	15.43	16.36	15.26	16.16	15.94	15.52	16.24	15.90	15.71	15.44
Fe_2O_3	2.47	1.86	4.60	3.74	2.53	2.91	3.41	2.17	2.84	2.11	1.97	2.77
FeO	4.21	3.69	5.98	2.36	3.07	2.44	2.86	1.60	2.85	4.13	3.01	3.46
MgO	3.01	3.70	3.52	2.54	3.77	3.26	2.34	1.52	2.74	4.38	3.67	3.15
CaO	4.46	4.69	4.64	4.11	4.80	4.49	4.85	3.44	4.81	6.11	5.67	4.82
Na_2O	3.94	3.30	3.60	5.35	3.82	4.08	3.86	3.49	4.18	3.71	3.57	3.78
K_2O	3.30	2.97	2.31	4.68	3.99	3.81	3.90	4.10	3.04	1.55	2.03	3.23
H_2O+	0.74	0.82	0.98	1.04	1.03	1.49	1.12	1.40	0.69	1.11	1.05	1.01
TiO_2	0.91	0.89	0.73	0.76	0.58	0.64	0.88	0.55	0.72	0.66	0.45	1.01
ZrO_2	0.01	0.01	0.00	0.03	....	....	0.01	0.01	....	....	....	....
P_2O_5	0.11	0.20	0.08	0.19	0.32	0.30	0.34	0.13	0.31	0.17	0.15	0.29
MnO	0.09	0.08	0.16	0.10	0.10	0.06	0.12	0.04	0.11	0.06	0.09	0.10
BaO	0.01	0.01	0.01	0.02	0.15	0.08	0.07	0.05	0.04	0.05	0.05	0.05
Incl.	0.13	0.06	0.15	0.18	0.21	0.25	0.21	0.18	0.05	0.07	0.09	0.12
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. New England and New York. 213 analyses.
2. Appalachia (New Jersey and Pennsylvania to Georgia). 188 analyses.
3. Algonkian Region (Michigan, Wisconsin, and Minnesota). 66 analyses.
4. Arkansas-Texas, including Missouri. 50 analyses.
5. Wyoming, including South Dakota and Yellowstone Park. 134 analyses.
6. Montana, including Idaho. 133 analyses.
7. Colorado. 171 analyses.
8. Utah and Nevada. 79 analyses.
9. Arizona and New Mexico. 79 analyses.
10. Washington and Oregon. 51 analyses.
11. California. 175 analyses.
12. United States. 1351 analyses, including analyses of 12 highly femic and titaniferous rocks omitted from the other columns.

AVERAGE IGNEOUS ROCKS, EUROPE

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	59.84	59.10	62.39	56.89	59.83	64.04	60.59	58.83	56.93	60.69	58.98	54.22	64.73
Al_2O_3	15.12	13.80	15.16	15.54	16.08	14.24	16.43	14.44	15.86	14.67	16.28	16.30	15.92
Fe_2O_3	3.17	3.14	2.40	2.69	3.65	3.65	2.75	3.35	3.72	2.76	2.53	4.28	3.15
FeO	3.67	4.57	3.04	3.57	3.21	3.41	2.88	3.91	3.78	3.28	3.44	5.54	2.28
MgO	3.61	4.80	3.79	4.57	2.26	1.82	2.16	4.63	4.15	4.56	3.03	5.02	1.76
CaO	4.97	5.41	3.92	4.43	3.64	3.25	3.35	5.56	6.45	4.37	5.16	7.60	4.49
Na_2O	3.73	3.55	3.70	4.56	5.10	3.70	6.11	3.45	3.61	3.52	3.72	2.99	3.69
K_2O	3.40	2.68	3.23	4.47	3.52	3.82	3.96	3.04	2.96	3.56	4.67	1.92	2.56
H_2O^+	1.24	1.44	1.46	1.19	0.75	0.84	0.71	1.40	1.45	1.68	0.94	1.17	1.03
TiO_2	0.83	0.97	0.75	1.34	1.64	0.73	0.56	0.87	0.58	0.65	0.85	0.66	0.31
P_2O_5	0.23	0.22	0.12	0.34	0.12	0.25	0.27	0.29	0.27	0.19	0.22	0.07	0.03
MnO	0.08	0.14	0.01	0.07	0.10	0.15	0.19	0.04	0.14	0.03	0.04	0.14	0.03
Incl.	0.11	0.18	0.03	0.34	0.10	0.10	0.05	0.18	0.10	0.04	0.14	0.09	0.02
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Europe. 1985 analyses.
2. British Islands. 171 analyses.
3. France, including Corsica. 163 analyses.
4. Iberia (Spain and Portugal). 33 analyses.
5. Norway, including Iceland. 107 analyses.
6. Sweden, including Spitzbergen. 206 analyses.
7. Finland, including Kola. 59 analyses.
8. Germany. 474 analyses.
9. Austria-Hungary-Bohemia, excluding Tyrol. 148 analyses.
10. Switzerland, including Tyrol. 217 analyses.
11. Italy, including Sicily, Sardinia, and islands. 276 analyses.
12. Russia, including Urals and Caucasus, excluding Finland and Siberia. 98 analyses.
13. Balkania, including Greece and Archipelago. 33 analyses.

AVERAGE IGNEOUS ROCKS, AFRICA AND ASIA

	1	2	3	4	5	6	7	8
SiO_2	58.21	54.67	50.59	56.02	61.92	61.81	59.72	61.02
Al_2O_3	15.28	16.21	15.81	15.68	15.49	15.73	16.51	15.97
Fe_2O_3	3.52	3.02	4.44	3.48	3.17	2.07	3.18	2.92
FeO	3.73	4.93	5.79	4.41	2.75	4.41	2.95	3.21
MgO	3.51	4.21	5.79	4.04	2.63	2.47	3.03	2.76
CaO	5.09	6.51	7.36	5.87	4.50	5.16	5.76	5.17
Na_2O	4.83	4.36	4.27	4.60	4.10	3.11	3.78	3.69
K_2O	3.28	3.05	2.31	3.07	3.23	2.51	3.05	2.99
H_2O^+	1.26	1.13	1.47	1.25	1.23	1.48	1.11	1.24
TiO_2	0.84	1.44	1.63	1.14	0.68	0.76	0.50	0.62
P_2O_5	0.20	0.35	0.43	0.27	0.12	0.27	0.18	0.18
MnO	0.07	0.01	0.04	0.05	0.10	0.17	0.14	0.15
BaO	....	....	....	....	....	....	....	....
Incl.	0.18	0.11	0.07	0.12	0.08	0.03	0.09	0.08
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Africa, continental. 223 analyses.
2. Madagascar, including Reunion. 140 analyses.
3. South Atlantic Islands (Azores, Canaries, Madeira, Cape Verde, Ascension, St. Helena). 56 analyses.
4. Africa and islands, including Madagascar and Atlantic Islands. 419 analyses.
5. Asia, continental. 114 analyses.
6. Japan. 69 analyses.
7. Malaysia, including Philippines. 129 analyses.
8. Asia, including continent, Malaysia and Japan. 312 analyses.

AVERAGE IGNEOUS ROCKS, AUSTRALASIA, POLYNESIA, ANTARCTICA

1	2	3	4
60.16	58.04	50.03	53.66
14.74	15.30	15.51	16.82
2.60	3.83	3.88	4.01
4.41	3.99	6.23	5.34
3.76	3.95	6.62	4.67
5.03	5.39	7.99	7.59
3.50	3.78	4.00	3.58
3.03	2.93	2.10	2.32
1.19	1.70	1.16	0.93
1.01	0.71	1.96	0.87
0.26	0.19	0.25	0.17
0.15	0.09	0.15	0.03
0.02	....	....	....
0.14	0.10	0.12	0.01
100.00	100.00	100.00	100.00

1. Australia, including Tasmania. 287 analyses.
2. New Zealand, including dependent islands. 134 analyses.
3. Polynesia (Hawaiian Islands, etc.). 72 analyses.
4. Antarctica and adjacent islands. 103 analyses.

AVERAGE CHEMICAL COMPOSITION OF THE IGNEOUS ROCKS OF THE EARTH

SiO_2	59.12
Al_2O_3	15.34
Fe_2O_3	3.08
FeO	3.80
MgO	3.49
CaO	5.08
Na_2O	3.84
K_2O	3.13
H_2O^+	1.15
CO_2	0.101
TiO_2	1.050
ZrO_2	0.039
P_2O_5	0.299
Cl	0.048
F	0.030
S	0.052
$(Ce,Y)_2O_3$	0.020
Cr_2O_3	0.055
V_2O_3	0.026
MnO	0.124
NiO	0.025
BaO	0.055
SrO	0.022
Li_2O	0.008
Cu	0.010
Zn	0.004
Pb	0.002
	100.000

AVERAGE COMPOSITION OF IGNEOUS ROCKS IN TERMS OF ELEMENTS

		1	2	3
1	Oxygen	46.41	47.29	47.2
2	Silicon	27.58	28.02	28.0
3	Aluminum	8.08	7.96	8.0
4	Iron	5.08	4.56	4.5
5	Calcium	3.61	3.47	3.5
6	Sodium	2.83	2.50	2.5
7	Potassium	2.58	2.47	2.5
8	Magnesium	2.09	2.29	2.5
9	Titanium	0.720	0.46	0.33
10	Phosphorus	0.157	0.13	0.22
11	Hydrogen	0.129	0.16	0.17
12	Manganese	0.124	0.078	0.075
13	Chlorine	0.096	0.063	0.04–.025
14	Barium	0.081	0.093	0.03
15	Sulphur	0.080	0.10	0.06
16	Chromium	0.068	0.034	0.01
17	Zirconium	0.052	0.017	0.02–.01
18	Carbon	0.051	0.13	0.22
19	Vanadium	0.041	0.017	0.00x
20	Strontium	0.034	0.034	0.005
21	Nickel	0.031	0.020	0.005
22	Fluorine	0.030	0.10	0.04–.025
23	Cerium, Yttrium	0.020	.....	0.00x,x
24	Copper	0.010	.....	0.000,xx
25	Lithium	0.005	0.004	0.004
26	Zinc	0.004	.....	0.000,x
27	Cobalt	0.003	.....	0.00x,x
28	Lead	0.002	.....	0.000,x
29	Boron	0.001	.....	0.00x
30	Glucinum	0.001	.....	0.00x
		100.000	100.000	100.000

1. Igneous rocks. Clarke and Washington, 1922.
2. Igneous rocks. Clarke, *Bull.* **695,** 1920, p. 28.
3. Igneous rocks. Vogt, *Zeits. prakt. Geol.*, **1898,** p. 324.

AVERAGE IGNEOUS ROCKS, NORTHERN NORTH AMERICA

	1	2	3	4	5	6
SiO_2	60.19	57.14	63.31	56.19	52.70	58.34
Al_2O_3	15.76	15.48	16.67	16.67	16.38	15.79
Fe_2O_3	2.87	3.93	2.18	3.31	4.58	2.21
FeO	3.67	4.72	2.46	4.65	5.83	3.99
MgO	3.16	1.55	2.25	3.39	3.27	4.57
CaO	4.80	3.51	5.05	5.34	5.29	5.66
Na_2O	3.90	6.98	3.85	4.40	4.88	3.54
K_2O	3.07	3.25	2.82	3.00	2.65	3.18
H_2O^+	1.01	1.12	0.78	1.08	1.09	1.14
TiO_2	1.01	1.50	0.77	1.25	2.20	0.69
ZrO_2	0.01	0.12	....	....	....	....
P_2O_5	0.26	0.19	0.18	0.19	0.21	0.33
MnO	0.10	0.21	0.10	0.13	0.17	0.14
BaO	0.04	....	....	0.04	0.06	0.11
Incl.	0.15	0.30	0.12	0.26	0.59	0.31
	100.00	100.00	100.00	100.00	100.00	100.00

1. North America, including Greenland, Mexico, Central America, and West Indies 1709 analyses.
2. Greenland, including East and West Greenland and Ellesmere Land. 41 analyses.
3. Alaska. 24 analyses.
4. Canada, including Alaska, East Canada, and British Columbia. 188 analyses.
5. East Canada, including Ontario, Quebec, Maritime Provinces, and Newfoundland. 99 analyses.
6. British Columbia, including Alberta. 60 analyses.

AVERAGE IGNEOUS ROCKS, MIDDLE AND SOUTH AMERICA

	1	2	3	4	5	6
SiO_2	59.11	58.70	61.34	61.06	61.85	54.92
Al_2O_3	16.58	18.30	15.20	15.17	16.51	16.29
Fe_2O_3	2.88	2.85	3.03	2.42	3.03	4.05
FeO	4.11	4.20	3.30	4.07	2.28	3.53
MgO	3.07	3.36	3.47	4.65	2.29	4.33
CaO	5.73	7.08	4.88	5.91	4.55	5.28
Na_2O	4.10	3.15	4.09	3.29	4.47	5.11
K_2O	2.32	0.99	2.69	1.74	2.69	3.57
H_2O	1.04	0.79	1.05	0.73	1.11	1.55
TiO_2	0.63	0.45	0.56	0.49	0.75	0.87
P_2O_5	0.25	0.08	0.11	0.07	0.25	0.11
MnO	0.06	0.02	0.12	0.18	0.22	0.37
Incl.	0.12	0.03	0.16	0.13	....	....
	100.00	100.00	100.00	100.00	100.00	100.00

1. Mexico and Central America. 47 analyses.
2. West Indies. 82 analyses.
3. South America. 138 analyses.
4. British Guiana. 45 analyses.
5. Andes Mountains. 56 analyses.
6. Eastern Brazil (including Paraguay and eastern Argentina). 20 analyses.

RARER ELEMENTS IN IGNEOUS ROCKS

	1	2
Rubidium	.000,x	.00x,x
Arsenic	.000,x	.00x,x
Molybdenum	.000,x	.000,0x
Tin	.000,x	.00x,x
Bromine	.000,x	.00x
Caesium	.000,0x	.000,00x
Scandium	.000,0x	.000,000,000,xx
Antimony	.000,0x	.00x,x
Cadmium	.000,0x	.000,00x
Mercury	.000,0x	.000,00x

RARER ELEMENTS IN IGNEOUS ROCKS (*Continued*)

	1	2
Iodine	.000,0x	.00x,x
Bismuth	.000,00x	.000,000,x
Tungsten	.000,00x	.000,00x
Thorium	.000,00x	.000,000,x
Columbium, Tantalum	.000,00x	.000,000,x
Uranium	.000,00x	.000,00x
Silver	.000,00x	.000,00v,x
Selenium	.000,00x	.000,000,x
Platinum	.000,000,x	.000,000,0x
Tellurium	.000,000,x	.000,000,0x
Gold	.000,000,x	.000,000,0x
Thallium	.000,000,0x	.000,000,00x
Indium	.000,000,00x	.000,000,00x
Gallium	.000,000,00x	.000,000,00x
Germanium	.000,000,000,x	.000,000,000,x
Radium	.000,000,000,00x	.....

1. Clarke and Washington, 1922.
2. Vogt, 1898.

ELEMENTS IN THE LITHOSPHERE, HYDROSPHERE, AND ATMOSPHERE

	1	2	3	4
Oxygen	49.19	47.80	46.68	46.41
Silicon	25.71	26.65	27.60	27.58
Aluminum	7.50	7.79	8.05	8.08
Iron	4.68	4.88	5.03	5.08
Calcium	3.37	3.49	3.63	3.61
Sodium	2.61	2.72	2.72	2.83
Potassium	2.38	2.48	2.56	2.58
Magnesium	1.94	2.01	2.07	2.09
Hydrogen	0.872	0.497	0.145	0.129
Titanium	0.648	0.684	0.696	0.720
Chlorine	0.228	0.162	0.095	0.096
Phosphorus	0.142	0.150	0.152	0.157
Carbon	0.139	0.095	0.149	0.051
Manganese	0.108	0.116	0.116	0.124
Sulphur	0.093	0.086	0.100	0.080
Barium	0.075	0.078	0.079	0.081
Chromium	0.062	0.065	0.066	0.068
Zirconium	0.048	0.050	0.052	0.052
Vanadium	0.038	0.040	0.041	0.041
Strontium	0.032	0.034	0.034	0.034
Fluorine	0.030	0.030	0.030	0.030
Nickel	0.030	0.031	0.031	0.031
Nitrogen	0.030	0.016	....	....
Cerium, Yttrium	0.019	0.020	0.020	0.020
Copper	0.010	0.010	0.010	0.010
Lithium	0.005	0.005	0.005	0.005
Zinc	0.004	0.004	0.004	0.004
Cobalt	0.003	0.003	0.003	0.003
Lead	0.002	0.002	0.002	0.002
Boron	0.001	0.001	0.001	0.001
Glucinum	0.001	0.001	0.001	0.001
	100.000	100.000	100.000	100.000

1. Average composition. Ten-mile crust, hydrosphere, and atmosphere.
2. Average composition. Twenty-mile crust, hydrosphere, atmosphere.
3. Average composition. Ten-mile crust, igneous and sedimentary rocks.
4. Average composition. Ten-mile crust. Igneous rocks.

The lithosphere is assumed to be made up as follows: Igneous rocks 95.00%; shale 4.00%; sandstone 0.75%; limestone 0.25%.

In the calculations involving the atmosphere and hydrosphere the thickness of the crust is assumed to be ten (or twenty) miles.

* Published with the permission of the Director of the U. S. Geological Survey.

[1] H. S. Washington, "Chemical Analyses of Igneous Rocks," *U. S. Geol. Survey, Prof. Paper* **99** (1917).

[2] F. W. Clarke, "The Data of Geochemistry," *U. S. Geol. Survey, Bull.* **695**, 1920 (22 and 33).

DARK NEBULAE

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1. It is now generally believed that many of the dark markings in the Milky Way, and dark starless regions in the sky, are produced by the interposition of huge obscuring clouds between us and the remoter stars. A long list of such dark markings has been given by Barnard,[1] who has done more than any one else to point out their importance and probable nature. In some cases, as in the Pleiades, Orion and Ophiuchus, these "regions of obscuration" merge into faintly luminous nebulosity in the vicinity of certain stars, in such a way that there can be no doubt that they lie near these stars in space.

It thus appears that the obscuring masses or dark nebulae in Ophiuchus and Scorpius are at a distance of from 100 to 150 parsecs, those in Taurus at probably about the same distance, and those in Orion some 200 parsecs from us, while the dimensions of the individual clouds are themselves measured in parsecs.

The occurrence of these three great regions of obscuration within a distance which is so small compared with that of the galactic clouds indicates that such objects are probably of great cosmical temperature.

2. These dark nebulae usually appear to be quite opaque. In some cases the stars can be seen faintly through them, apparently without much change in color; but in certain instances[2] stars imbedded in dense luminous nebulosity are abnormally red.

Of the various forms in which matter may be distributed in space, by far the most efficient in producing obscuration is fine dust, since this has the greatest superficial area per unit of mass. In a cloud composed of spherical particles of radius r and density ρ, distributed at random so that the average quantity of matter per unit volume is d, the extinction of a beam of light in passing through this cloud will be e stellar magnitudes per unit of distance, where $e = 0.814\ qd/\rho r$.