1909

Investigation of hindered settling ratio of galena, sphalerite and pyrite as compared to quartz in air

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INVESTIGATION OF HINDERED SETTLING RATIO OF GALENA,SPHALERITE AND PYRITE AS COMPARED TO QUARTZ IN AIR.

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PROBLEM.

The object of this thesis is to determine the hindered settling ratios in air, of Galena, of Pyrite, and of Sphalerite as compared to Quartz.

DEFINITION OF HINDERED SETTLING.

Professor Richards, in his book, "Ore Dressing", page 610, says,-"Hindered settling takes place when particles of mixed sizes, shapes and gravities inaa mass, free to move among themselves, are sorted in a rising current of water, the rising current having much less velocity than the free settling velocity of the particles, but yet enough so that the particles are kept in motion. The arrangement of particles is so positive that if one of them be moved up or down from its chosen companions, it will be found, when set free, to return immediately to practically the same group as before."

A given particle may occupy any position in the community of particles if it has the proper neighbors. The ability of its neighbors to hinder, to elbow, determines whether a particle shall be at the top of the mass or at the bottom even though the rising current remains the same.

Prof. Richards used water in his work, but in the following tests air was used as a medium in which hindered settling was to take place.

The hindered settling ratio of Galena as compared to Quartz means, the ratio of the diameter of a quartz particle to the diameter of a Galena particle with which it is in equilibrium: i.e. with which it occupies the same level in the sorting column. The column of ore in the tube is called the sorting column.

MINERALS USED.

The minerals used were pure (with the exception of Galena,-note its low specific gravity). In each case the minerals were crushed through an eight mesh (2.628 m m.) screen. For the tests a volume of galena was mixed with an equal volume of quartz. The same was done with sphalerite and quartz and with pyrite and quartz.

SPECIFIC GRAVITY OF MINERALS USED.

Table I.

Mineral	Specific Gravity
Quartz	2.590
Galena	6.834
Pyrite	4.738
Blende	4.098

The specific gravity of the minerals used was determined in a specific gravity flask.

The low specific gravity of the Galena must be due to some impurity. Although seemingly pure cubic lead sulphide, yet the galena contained only 75% lead. Pure galena should contain 87% lead.

APPARATUS USED IN TESTS.

Plate I

Plate I.

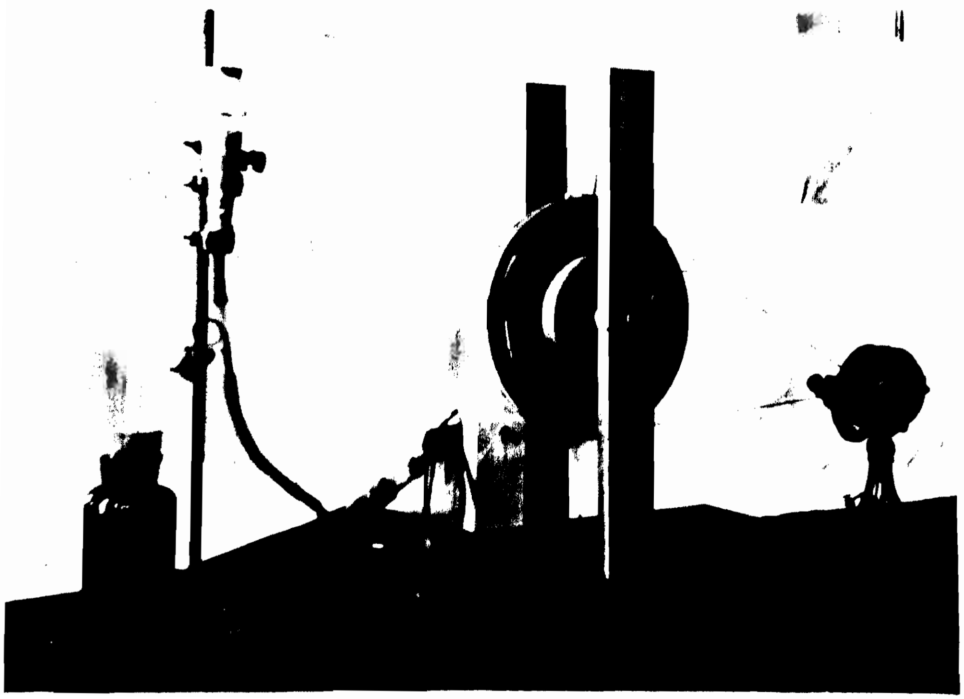


Plate I shows the apparatus used in the tests made to determine the ratios of hindered settling. It consists of a tubular classifier, conical at the bottom, similar to the one used by Prof. Richards in his tests with water. This tube was chosen as the best for the work from several which were used in the preliminary experiments. A steady current of air was admitted through the tubing into the bottom of the glass cone. The very fine material was blown out at top and caught in bottle as shown in the picture.

It was found that with a steady current of air it was impossible to get a thorough and yet not too violent agitation of the ore column, either the top layers were blown out of the tube or the bottom layers were not agitated.

A device, as shown in center of picture was used for the purpose of causing pulsations in the bed. It consists of a revolving disc which intermittently strikes the rubber tube, conveying the air to the air column. This causes a series of pulsations which gave perfect agitation in the ore column. The revolving disc is driven by a small motor, shown at the right of the picture.

In this manner the column of ore in the tube was kept in motion for one (1) hour, thereby allowing all grains to properly layer themselves. When all was in equilibrium ten (10) layers were drawn from the tube. Each draw represented a certain layer of the ore column.

Each layer was put through a nest of screens, ranging from eight mesh to two hundred mesh, the size of the holes in the screens ranging from 2.628 mm. to 0.076 mm. The grains remaining on each successive screen were then placed on a chart in its proper position, and a photograph taken as seen in Plates II, III and IV. This is similar to the method used by Prof. Richards in his experiments with water.

The grains are shown arranged in the form of a graphical plot. The numbers, horizontally 1, ,3,4, on the Plates II, III and IV, represent each successive layer drawn from tube. Vertically the numbers represent the average diameter of the grains in mm. This diameter is taken as the average between the holes in the screen through which the grains passed and the size of holes in screen on which they remain.

SIZE OF HOLES IN SCREENS USED.

To determine the average diameter of the grams on each screen, the size of holes in the screens were carefully measured. For this purpose a dividing engine was used. A sample of the screen was placed upon a traveling platform which moves under a microscope. The distance the platform moves can be measured to 1/100 of a m m. by a dial.

The diameter of wire in the screens was measured and an average taken. By counting the number of wires and spaces that pass microscope cross hairs in a distance, registered by dial and deducting the space occupied by the wires for that distance, the size of hole can be readily calculated. In determining the size of holes of the screens four observations were taken, two in each direction, over different parts of the sample of screen used.

The average data and size of holes of screen used is recorded in Table II

Table II

Screen Mesh.	Ave Dist. registered by dial. m m.	Ave.of No.of Wires and spaces.	Ave. Diam of Wires m m.	Ave Linear size of hole in screen	Ave. Diam of grains resting on screen m m.
8	15.24	4.5	0.759	2.628	
10	15.42	6	0.621	.1.949	2.288
12	11.86	6	0.512	1.462	1.755
14	10.84	6	0.497	1.309	1.385
16	16.03	100	0.445	1.158	1.253
18	13.95	10	0.421	0.974	1.066
20	20.66	16	0.381	0.909	0.941
24	25.60	24	0.329	0.757	0.823
30	25.45	30	0.294	0.554	0.645
35	22.25	30	0.266	0.476	0.515
40	25.60	40	0.259	0.381	0.428
50	20.25	40	0.236	0.270	0.325
70	23.06	60	0.174	0.210	0.240
100	22.11	80	0.120	0.156	0.183
150	23.71	150	0.077	0.087	0.120
200	19.81	150	0.056	0.076	0.083
60	21.62	50	0.200	0.232	
80	23.34	70	0.152	0.181	
120	21.52	100	0.102	0.113	

The screens at bottom of table 60,80 and 120 mesh,were measured but were not used in the tests.

Table III(a)

GALENA AND QUARTZ.

Layer 4.

Mesh	% PbS in Hill	Total wt. of hill gm	Wt. SiO_2 in hill gm	Wt. PbS. in hill gm	Wt. X Diam SiO_2	Wt. X Diam. PbS
10	5	3.955	3.766	0.189	8.617	0.434
12	6	3.416	3.194	0.222	8.605	0.389
14	14	1.885	1.625	0.260	2.250	0.360
16	20	1.385	1.005	0.380	1.240	0.468
18	50	1.935	0.985	0.950	1.050	1.012
20	72	1.890	0.520	1.370	0.508	1.287
24	85	3.567	0.467	3.100	0.304	2.551
30	95	8.432	0.422	8.010	0.472	5.166
35	100	5.963	0.000	5.963	0.000	3.070
40	100	4.457	0.000	4.457	0.000	1.907
50	100	10.320	0.000	10.320	0.000	3.354
70	100	4.573	0.000	4.573	0.000	1.097
100	100	0.035	0.000	0.035	0.000	0.006
150	100	0.035	0.000	0.035	0.000	0.004
200	100	0.000	0.000	0.000	0.000	0.000
			11.984	39.864	20.046	21.105

Table III (a)

GALENA AND QUARTZ

Layer 5.

Mesh	% PbS in Hill	Total wt. of hill gm.	Wt. SiO_2. in hill gm.	Wt. PbS in hill gm.	Wt. X Diam. SiO_2	Wt. X Diam. PbS.
110	0	4.703	4.703	0.000	10.760	0.000
12	0	4.515	4.515	0.000	7.923	0.000
14	0	5.035	5.035	0.000	6.973	0.000
16	1	2.373	2.338	0.035	2.871	0.043
182	2	2.437	2.387	0.050	2.545	0.053
20	1	1.116	1.096	0.020	1.020	0.016
24	2	1.292	1.257	0.035	1.036	0.028
30	8	1.330	1.214	0.116	1.783	0.075
35	20	0.694	0.586	0.138	0.286	0.071
40	63	0.867	0.321	0.546	0.137	0.234
50	92	0.342	0.268	0.074	0.087	0.010
70	99	5.016	0.050	4.966	0.012	1.200
100	100	0.079	0.000	0.079	0.000	0.014
150	100	0.530	0.000	0.530	0.000	0.044
200	000	0.000	0.000	0.000	0.000	0.000
			23.750	9.589	34.433	2.788

Table III (b)

GALENA AND QUARTZ.

Layer 6.

Mesh	PbS in Hill	Total wt. of hill gm.	Wt. SiO in hill gm.	Wt. PbS. in hill gm.	Wt. x Diam. SiO	Wt. X Diam. PbS.
10	0	4.167	4.167	0.000	9.534	0.000
12	0	4.603	4.603	0.000	8.078	0.000
14	0	3.950	3.950	0.000	5.430	0.000
16	0	2.368	2.368	0.000	2.920	0.000
18	0	2.315	2.315	0.000	2.467	0.000
20	0	1.136	1.136	0.000	1.067	0.000
24	1	1.500	1.485	0.015	1.2[illegible]2	0.012
30	1	1.843	1.824	0.0184	1.176	0.042
35	9	0.900	0.819	0.0810	0.422	0.042
40	22	0.759	0.592	0.167	0.243	0.071
50	84	2.638	0.422	2.216	0.137	0.742
70	96	4.170	0.167	4.003	0.040	0.960
100	99	2.058	0.021	2.037	0.003	0.372
150	100	1.786	0.000	1.786	0.000	0.214
200	000	0.000	0.000	000	000	000
			23.869	10.323	32.769	2.4250

Table III (b)

GALENA AND QUARTZ.

Layer 7.

Mesh	% PbS in hill	Total wt. of hill gm.	Wt. SiO in hill gm.	Wt. PbS in hill gm.	Wt. X Diam SiO	Wt. X Diam. PbS
10	0	2.190	2.190	0.000	5.010	0.000
1[illegible]	0	3.430	3.430	0.000	6.039	0.000
1[illegible]	0	3.491	3.491	0.000	4.835	0.000
16	0	2.107	2.107	0.000	2.597	0.000
18	0	2.303	2.303	0.000	2.454	0.000
20	0	1.432	1.432	0.000	1.346	0.000
24	0	1.922	1.922	0.000	1.571	0.000
30	3	2.040	1.979	0.061	1.275	0.039
35	8	0.669	0.616	0.053	0.317	0.027
40	12	0.990	0.872	0.118	0.373	0.003
50	64	2.640	0.941	1.699	0.305	0.055
70	93	4.323	0.303	4.020	0.072	0.964
100	98	2.307	0.276	2.031	0.050	0.371
150	99	2.562	0.026	2.536	0.003	0.304
200	100	0.807	0.000	0.807	0.000	0.067
			21.888	11.325	26.247	1.830

Table IV (b)

BLENDE AND QUARTZ.

Layer 4.

Mesh	% ZnS in	Total wt. hill gm	Wt. ZnS in hill gm.	Wt. SiO in hill gm	Wt. X Diam. ZnS.	Wt. X Diam. SiO_2
10	42	5.400	2.273	3.127	5.201	7.154
12	47	4.375	2.067	2.308	3.629	4.051
14	60	5.810	3.530	2.280	5.239	3.155
16	70	3.192	2.260	0.932	2.786	1.123
18	76	3.880	2.970	0.910	3.166	0.970
20	86	3.030	2.606	0.424	2.449	0.398
24	93	3.470	3.227	0.243	2.456	0.200
30	98	2.925	2.666	0.259	1.720	0.346
35	98	1.278	1.252	0.026	0.644	0.013
40	98	0.930	0.911	0.019	0.389	0.008
50	100	1.290	1.290	0.000	0.419	0.00
70	100	0.348	.348	0.000	0.835	0.000
100	000	0.000	.000	0.000	0.000	0.000
150	000	0.000	.000	0.000	0.000	0.000
200	000	0.000	.000	0.000	0.000	0.000
			25.400	10.528	29.132	17.418

Table IV (b)

BLENDE AND QUARTZ.

Layer 5.

Mesh	% ZnS in hill	Total wt. hill gm	Wt. Zns in hill gm	Wt. SiO in hill gm	Wt. X Diam Zns.	Wt. X Diam. SiO_2
10	5	4.538	0.265	4.273	0.606	9.775
12	7	3.529	0.258	3.271	0.452	5.740
14	9	3.644	0.344	3.300	0.476	4.570
16	20	2.074	0.420	1.654	0.518	2.040
18	36	2.741	0.830	1.911	0.884	2.037
20	54	0.663	0.898	0.765	0.844	0.719
24	73	2.690	2.083	0.607	1.714	0.499
30	95	3.257	3.093	0.164	1.995	0.105
35	95	1.700	1.615	0.085	0.830	0.043
40	95	1.544	1.467	0.077	0.626	0.032
50	98	2.157	2.113	0.034	0.685	0.010
70	98	0.784	0.768	0.016	0.008	0.000
100	100	0.049	0.049	0.000	0.000	0.000
150	000	0.000	0.000	0.000	0.000	0.000
200	000	0.000	0.000	0.000	0.000	0.000
			14.203	16.157	16.157	25.570

Table IV (a)

BLENDE AND QUARTZ.

Layer 6

Mesh	% Zns in hill	Total wt hill gm.	Wt. Zns in hill gm.	Wt SiO in hill gm.	Wt X Diam ZnS	Wt X Diam SiO_2
10	0	4.735	0.000	4.735	0.000	10.830
12	0	3.606	0.000	3.606	0.000	6.329
14	3	3.655	0.109	3.546	0.151	4.911
16	7	2.117	0.148	1.969	0.182	2.428
18	16	2.530	0.404	2.126	0.430	2.266
20	23	1.595	0.368	1.227	0.345	1.153
24	37	2.300	0.851	1.449	0.700	1.193
30	63	2.770	1.745	1.025	1.126	0.661
35	87	1.656	1.440	0.216	0.741	0.101
40	91	1.385	1.260	0.125	0.539	0.053
50	96	2.375	2.280	0.095	0.471	0.031
70	98	1.110	1.087	0.023	0.259	0.005
100	100	0.168	0.168	0.000	0.031	0.000
150	100	0.068	0.068	0.000	0.008	0.000
200	000	0.000	0.000	0.000	0.000	0.000
			9.928	20.142	4.983	20.961.

Table Iv (a)

BLENDE AND QUARTZ.

Layer 7

Mesh	% ZnS in hill	Total wt. hill gm	Wt.ZnS in hill gm	Wt.SiO in hill gm	Wt. X Diam. ZnS	Wt. X. Diam. SiO_2
10	0	2.808	0.000	2.808	0.000	6.424
12	0	3.590	0.000	3.590	0.000	6.300
14	0	3.500	0.000	3.500	0.000	4.848
16	1	2.236	0.022	2.214	0.027	2.730
18	5	2.936	0.147	2.789	0.156	2.974
20	12	1.734	0.208	1.526	0.195	1.434
24	21	2.083	0.437	1.646	0.359	1.355
30	49	2.918	1.459	1.459	0.941	0.940
35	65	1.724	1.020	0.704	0.525	0.362
40	75	1.314	0.985	0.329	0.421	0.141
50	93	2.652	2.476	0.176	0.804	0.057
70	95	2.026	o.924	0.102	0.641	0.024
100	95	0.638	0.606	0.032	0.111	0.005
150	95	0.595	0.565	0.030	0.067	0.003
200	95	0.148	0.140	0.008	0.011	0.000
			9.989	20;905	4.078	27.597

Table V (a)

Data for Pyrite and Quartz.

Layer 4.

Mesh	% FeS in hill	Total wt. hill gm.	Wt. SiO in hill gm.	Wt. FeS_2 in hill gm.	Wt X Diam SiO_2	Wt X Diam. FeS_2
10	88	6.162	.709	5.453	0.622	12.476
12	92	6.408	.308	6.100	0.540	10.705
14	97	6.538	.178	6.360	0.246	8.808
16	99	3.999	.049	3.950	0.060	4.870
18	99	4.910	.030	4.88	0.031	5.202
20	100	2.940	.000	2.940	0.000	.276
24	100	5.100	.000	5.100	0.000	4.197
30	100	4.546	.000	4.546	0.000	2.932
35	100	1.786	.000	1.786	0.000	.909
40	100	0.928	.000	.928	0.000	.397
50	100	1.860	.000	1.860	0.000	.070
70	100	0.153	.000	.153	0.000	.036
100	100	0.034	.000	.034	0.000	.006
150	000	0.00	.000	.000	0.000	.000
200	000	0.00	.000	.000	0.000	.000
			1.274	44.090	2.499	50.884

Table V (a)

PYRITE AND QUARTZ.

Layer 5

Mesh	% FeS_2 in mill	Total wt. mill gm.	Wt. SiO_2 in mill gm.	Wt. FeS_2 in mill gm.	Wt. X Diam SiO_2	Wt. X Diam FeS_2
10	00	6.932	6.932	0.000	15.860	0.000
12	10	3.926	3.548	0.378	6.226	0.663
14	22	3.095	2.415	0.680	3.342	0.941
16	23	1.800	1.400	0.400	1.726	0.493
18	41	1.838	1.078	0.760	1.149	0.810
20	50	0.968	0.493	0.475	0.463	0.446
24	63	1.660	0.607	0.053	0.499	0.866
30	86	2.716	0.486	2.330	0.313	1.506
35	95	2.090	0.110	1.980	0.566	1.010
40	98	1.398	0.038	1.360	0.016	0.585
50	100	2.659	0.000	2.659	0.000	0.764
70	100	1.666	0.000	1.666	0.000	0.399
100	100	0.420	0.000	.420	0.000	0.076
150	100	0.282	0.000	.282	0.000	0.035
200	000	0.0	0.000	.000	0.000	0.000
			17.105	14.443	30.160	8.594.

Table V

PYRITE AND QUARTZ.

Layer 6

Mesh	% FeS in hill	Total wt hill gm	Wt. SiO in hill gm	Wt. FeS_2 in hill gm	Wt X Diam SiO_2	Wt. X Diam. FeS_2
10	0	7.917	7.917	0.000	18.140	0.000
12	0	4.305	4.305	0.000	8.096	0.000
14	0	3.305	3.305	0.000	4.578	0.000
16	0	1.665	1.665	0.000	2.053	0.000
18	0	1.595	1.545	0.000	1.647	0.000
20	0	0.860	0.860	0.000	0.808	0.000
24	6	1.145	1.076	0.069	0.885	0.056
30	20	1.320	1.056	0.264	0.581	0.170
35	67	0.860	0.284	0.576	0.146	0.296
40	88	1.817	0.218	0.599	00083	0.684
50	96	2.133	0.086	2.047	0.027	0.665
70	98	1.758	0.036	1.720	0.008	0.412
100	100	0.643	0.000	0.643	0.00	0.119
150	100	0.158	0.000	0.158	0.000	0.018
200	0	0.000	0.000	0.000	0.000	0.000
			22.353	7.076	37.182	2.420

Table V

PHRITE AND QUARTZ.

Layer 7

Mesh	% FeS in hill	Total wt hill gm.	Wt SiO in hill gm.	Wt FeS_2 in hill gm	Wt.X Diam. SiO_2	Wt X Diam. FeS_2
10	00	4.100	4.100	0.000	9.402	0.000
12	00	4.043	4.043	0.000	7.097	0.000
14	00	3.550	3.550	0.000	4.916	0.000
16	00	2.180	2.180	0.000	2.683	0.000
18	00	1.886	1.886	0.000	2.011	0.000
20	00	1.046	1.046	0.000	0.983	0.000
24	00	1.696	1.696	0.000	1.393	0.000
30	5	1.330	1.264	0.066	0.815	0.042
35	23	0.726	0.560	0.166	0.288	0.085
40	58	0.832	0.350	0.482	0.149	0.210
50	86	2.180	0.306	1.874	0.099	0.609
70	95	2.860	0.143	2.717	0.034	0.652
100	96	1.080	0.043	1.037	0.007	0.189
150	98	1.378	0.028	1.350	0.003	0.162
200	100	0.600	0.000	0.600	0.000	0.049
			21.495	8.292	29.885	1.998

Table III gives the data from which was calculated the "hindered settling ratio" of galena as compared to quartz. Layers 4,5,6,and 7 were used,since these layers contained both galena and quartz.

The term "hill" used in the tables,refers to the material resting on each screen,and is seen as a single pile in the Photographic plot.

METHOD OF CALCULATING AVERAGE SIZE OF PARTICLE IN EACH LAYER.

For each layer the material remaining on every screen was weighed, the weight of galena in each hill was estimated and multiplied by its average diameter. These products for all the screens,for a given layer, were summed and divided by the total weight of galena in the layer. The quotient obtained is the average diameter of the galena in the layer or level. The average diameter of the quartz in the layer was determined in the same manner. The average diameter of the quartz divided by the average diameter of the galena is the hindered settling ratio for that particular layer. This method was used in each layer, for each set of minerals and results tabulated in Table VI.

Plate II

GALENA AND QUARTZ.

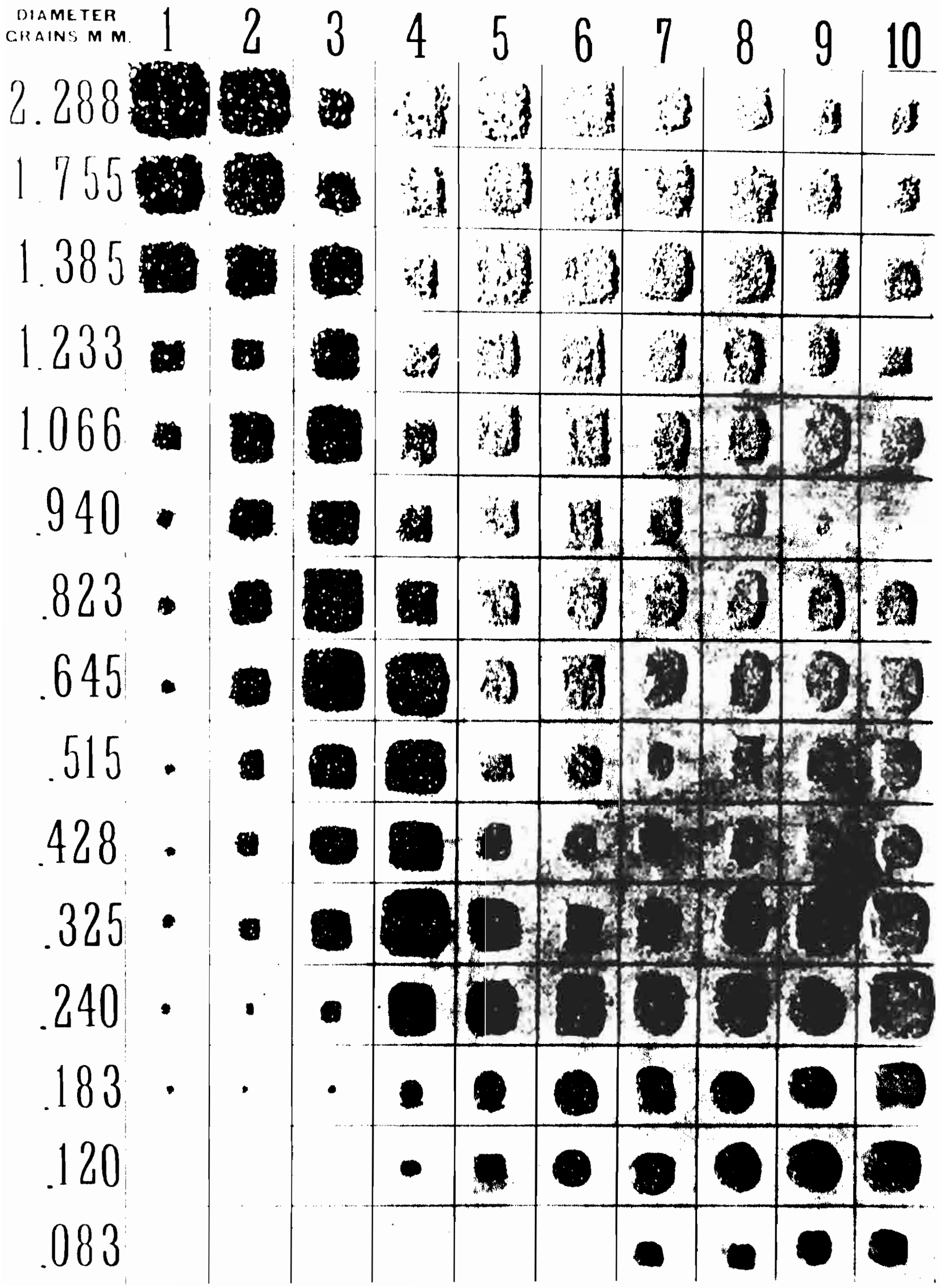


Plate III

SPHALERITE AND QUARTZ.

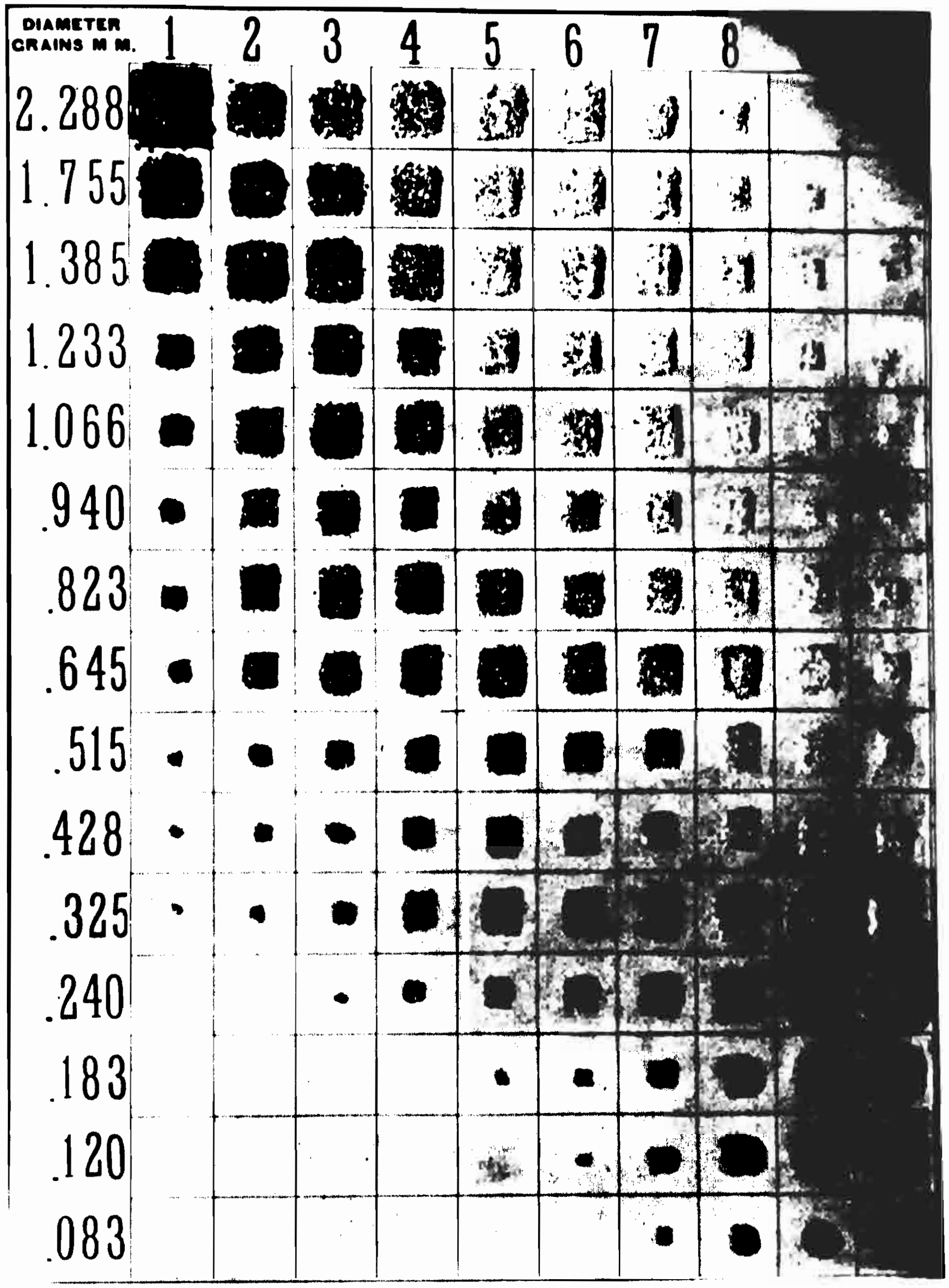
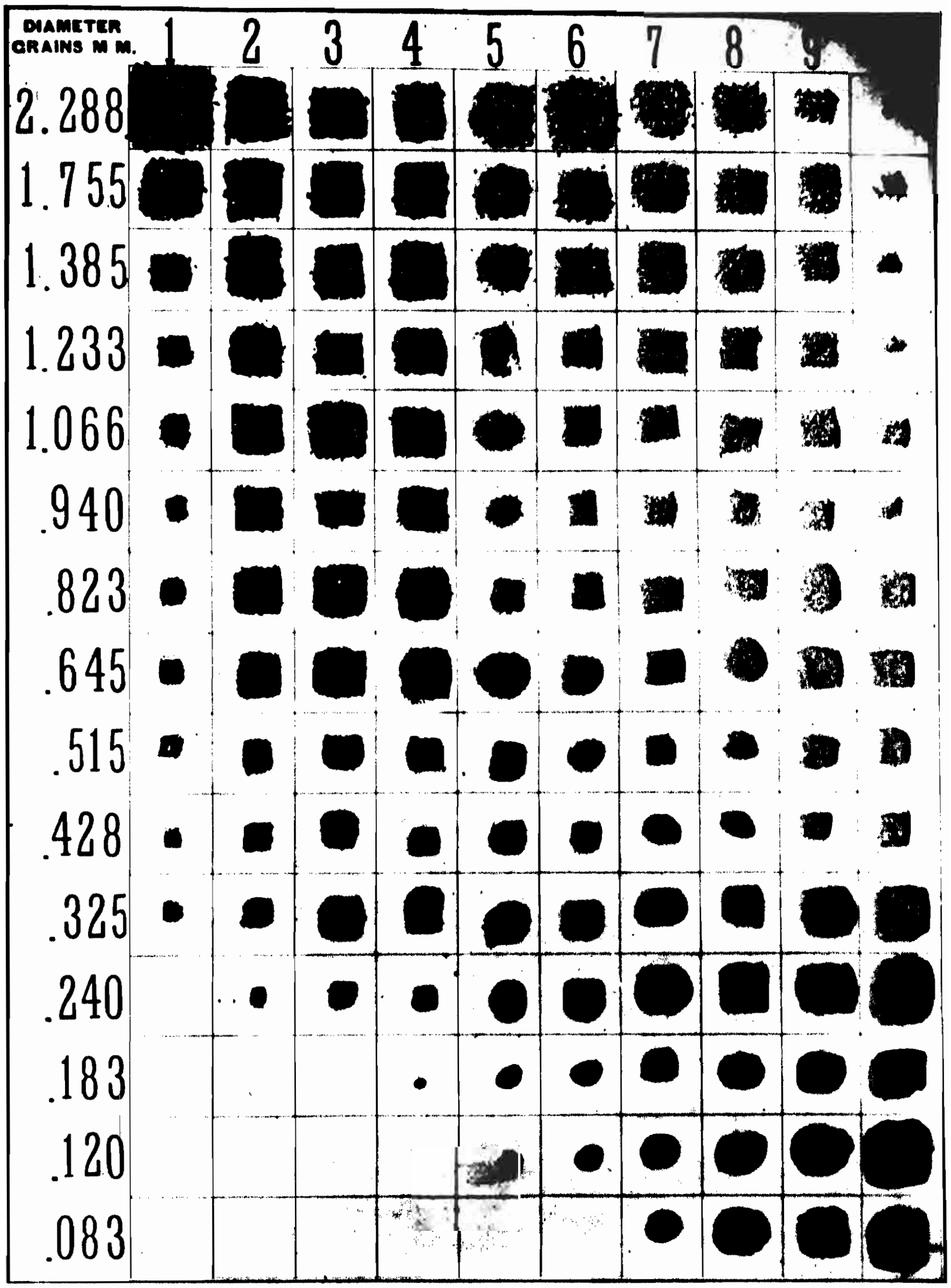


Plate IV.

PYRITE AND QUARTZ.



HINDERED SETTLING RATIO.

Table VI.

Ratio of Diameter of Quartz to that of Mineral Used.

Mineral	Layer 4	Layer 5	Layer 6	Layer 7	Average
Galena	3.21	5.00	6.00	10.6	6.2
Sphalerite	1.50	2.36	2.07	3.20	2.28
Pyrite	1.69	2.96	4.86	5.79	3.82

Practical Application of Results.

Referring to Table VI we see, that, in an air jig, for good results, the diameter of the largest particle of quartz should never be more than about 6 times the diameter of the smallest particle of galena. That the largest particle of quartz should not ne more than about three times the diameter of smallest particle of sphalerite. And that the largest particle of quartz should never be more than about four times the diameter of the smallest particle of pyrite, if in each case the quartz is always to layer itself above the smallest particle of heavy mineral.