

Supplementary materials of the manuscript entitled “A handheld instrument for the combined measurement of magnetic susceptibility and electrical conductivity, with application to meteorite classification”

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S1. Python script and raw data

The data is processed by python scripts running on a Jupyter notebook (<https://jupyter.org/>). The original Jupyter notebook and the raw data are available in a separated zip file. The raw data are in the csv files; the results for meteorites and terrestrial rocks are provided in Table S6-S8 in §S.5 of this supplementary material. Here is the list of the files in the Supplementary material S2.zip:

- **MetMetMET.csv**
The raw data of meteorites (162 samples). The labels of the columns are “official name” = official name of the meteorite, “mass” = mass of the sample in g, “C index” and “logX” = results of measurements by the meteorite meter, “group” = the group of the meteorite, “Class” = the working class name for the data processing, “Type” = petrologic type of chondrites, “W” = weathering grade of the ordinary chondrite, “logX_KLY2” and “logX_SM30” are $\log\chi_m$ values measured by KLY-2 and SM30.
- **MetMetWOC.csv**
The raw data of weathered ordinary chondrites (143 samples). The labels of the columns are same as MetMetMET.csv.
- **MetMetRock.csv**
The raw data of terrestrial rocks (54 samples). The labels of the columns are same as MetMetMET.csv.
- **ShippingTest.csv**
The result of quality check tests that is discussed in section 3.2. The labels of the columns are “Unit” = Unit name with serial number SN, “Item” = the type of measurement combined with name of the standard sample, “mass” = the mass of the sample in g, “#1 ... #5” = the n-th result of measurement indicated in Item label.
- **SupplMatPlotting V3.ipynb**
Jupyter notebook of data treatment. Please place the csv files at the same place of this file. A directory named “output” is necessary to store the output figures and tables.
- **SupplMatPlotting V3.html**
The html version of the Jupyter notebook, showing the python code and the result of execution.

The versions of the modules are Python 3.7.3, Matplotlib 3.0.2, Pandas 1.2.3, Numpy 1.20.3, and Scipy 1.6.2. Note that the scaling factor of the ellipse is based on the chi-squared function with degree of freedom of two (scipy.chi2.ppf method). 86 % of data distribute within mean ± 2 standard deviation if the data is 2-D and normally distributed, whereas it is 95 % for the 1-D normal distribution.

S2. Calibration and standard samples

The factor of sensitivity α (m^3/kg) of MetMet is calibrated using concrete cylinders with known magnetic susceptibility measured by KLY-2 (Lecoanet et al. 1999, Gattacceca et al., 2004; Table S2). The size is 40 cm in diameter and 20 cm in height.

Table S2 The magnetic susceptibility of concrete blocks measured by KLY-2 and the K value given by MetMet.

Name	KLY-2 $10^{-9} \text{ m}^3/\text{kg}$	MetMet K value $\times 10^9$
G3	1.84E+4	5.07E+6
G5	8.19E+3	2.20E+6
G7	9.72E+3	2.87E+6
G9	1.32E+4	3.66E+6
G11	1.36E+2	2.44E+5
G13	3.18E+1	1.00E+0
G14	1.08E+2	1.22E+5
G16	2.73E+3	9.77E+5

To calibrate the effect of sample size, we measured 58 basalt pebbles collected along the Durance river close to Saint-Paul-lez-Durance, France (Table S3). These pebbles have smooth surfaces and have aspect ratio in the 0.28 - 0.89 range, with an average aspect ratio of 0.55. We excluded the following samples from the calculation of the β value: samples with weak susceptibility ($K_{Total} < 150 \cdot 10^{-9} \text{ m}^3$), very flat samples with aspect ratio = $(\text{minor axis})/(\text{major axis} \cdot \text{minor axis})^{0.5} < 0.4$, as well as three other obvious outliers (Fig. S1a). The cross calibration of $\log\chi_m$ values for the basalt pebble among three different magnetic susceptibility meter (KLY2, SM30, and MetMet) shows very good linearity and almost on the 1:1 line (Table S2; Fig. S1b), except for the weak $\log\chi_m$ samples ($\log\chi_m < 2.5$; see §S3). The operating frequency for MetMet, KLY-2, and SM30 is respectively 100 kHz, 920 Hz, and 8 kHz.

Table S3 The size and the magnetic susceptibility of the basalt pebbles to calibrate the β value. The samples in italic are excluded from the calculation of β value due to the out-of-trend. Standard deviations (stdev) are shown when they measured 2 times or more. ¹Total magnetic susceptibility before mass correction. ²Rejected due to low aspect ratio. ³Rejected due to low total magnetic susceptibility. ⁴Other rejected samples.

Name	Vol. (cm^3)	Mass (g)	Aspect ratio	Total magnetic susceptibility (10^{-9} m^3)					$\log\chi_m$		
				KLY-2 K_{Total}	MetMet ¹ K_{Total}	MetMet ¹ /KLY-2 Ratio	Stdev	Stdev	MetMet	KLY-2	SM30
<i>III-1²</i>	45	132	0.38	1323.7	1296.0	86.1	0.98	0.065	4.14	4.00	4.06
<i>III-2²</i>	49	141	0.34	233.6	266.9	14.4	1.14	0.062	3.41	3.22	3.30
III-3	38	109	0.78	251.2	143.7	19.5	0.57	0.078	3.29	3.36	3.26
III-4	55	159	0.44	2102.4	1752.4	155.9	0.83	0.074	4.16	4.12	4.10
III-5	59	171	0.47	2593.8	2337.3	226.4	0.90	0.087	4.24	4.18	4.15
III-6	60	174	0.62	3146.3	2351.7	190.3	0.75	0.060	4.24	4.26	4.21
III-7	55	158	0.48	2636.0	1974.6	56.8	0.75	0.022	4.21	4.22	4.13
<i>III-8³</i>	145.3	421	0.7	69.1	138.3	46.1	2.0	0.667	2.56	2.21	2.28
III-9	86	249	0.45	3572.0	3029.7	227.6	0.85	0.064	4.16	4.16	4.16
<i>III-10⁴</i>	82	238	0.28	1153.2	1334.4	24.5	1.16	0.021	3.83	3.69	3.73
III-14	103	298	0.63	4439.5	3216.0	123.4	0.72	0.028	4.09	4.17	4.10

III-15 ³	144	418	0.63	64.3	91.4	0.0	1.42	0.000	2.38	2.19	2.26
III-16	99	288	0.51	7878.3	7700.2	834.3	0.98	0.106	4.49	4.44	4.39
III-17	90	260	0.44	3510.3	3383.0	371.3	0.96	0.106	4.19	4.13	4.20
III-18 ³	81	234	0.56	45.3	51.2	0.0	1.13	0.000	2.42	2.29	2.19
III-19	70	202	0.54	1280.1	1015.5	35.8	0.79	0.028	3.79	3.80	3.69
III-20	64	184	0.59	1037.7	684.8	56.9	0.66	0.055	3.67	3.75	3.66
III-21	50	145	0.40	627.5	475.3	44.8	0.76	0.071	3.65	3.64	3.56
III-22	45	129	0.37	216.1	160.2	13.3	0.74	0.062	3.24	3.22	3.17
III-23 ³	58	169	0.41	24.9	37.0	0.0	1.49	0.000	2.45	2.17	2.13
III-24	45	130	0.70	1977.6	1422.0	61.6	0.72	0.031	4.19	4.18	4.11
III-25 ³	26	76	0.43	31.8	16.6	0.0	0.52	0.000	2.59	2.62	2.65
III-26	42	121	0.68	1985.4	1282.8	45.1	0.65	0.023	4.18	4.21	4.16
III-27	34	99	0.63	981.8	679.5	54.3	0.69	0.055	4.03	4.00	4.01
III-28	36	103	0.50	398.4	271.4	22.7	0.68	0.057	3.60	3.59	3.52
III-29	26	75	0.48	1258.7	734.2	32.6	0.58	0.026	4.25	4.23	4.23
III-30	31	90	0.67	1956.8	1103.3	49.0	0.56	0.025	4.30	4.34	4.26
III-31	21	62	0.55	1081.9	520.7	49.7	0.48	0.046	4.23	4.24	4.21
III-32	19	54	0.65	855.7	387.2	18.1	0.45	0.021	4.19	4.20	4.18
III-33	24	70	0.63	1154.7	655.3	38.4	0.57	0.033	4.24	4.21	4.22
III-34	15	45	0.54	333.7	127.1	9.8	0.38	0.029	3.86	3.87	3.86
III-35	20	59	0.49	1661.7	809.6	25.8	0.49	0.016	4.46	4.45	4.45
III-36	14	42	0.62	193.5	54.6	0.0	0.28	0.000	3.55	3.67	3.61
III-37	15	42	0.54	1335.1	258.7	22.5	0.19	0.017	4.21	4.50	4.21
III-38	17	50	0.42	447.5	192.2	5.4	0.43	0.012	3.95	3.95	3.96
III-39	12	34	0.48	875.8	267.9	11.1	0.31	0.013	4.41	4.42	4.39
III-40	13	38	0.41	660.0	216.6	16.6	0.33	0.025	4.21	4.24	4.21
III-41	11	32	0.45	417.1	124.1	5.7	0.30	0.014	4.12	4.12	4.09
III-42 ³	11	33	0.48	5.3	7.3	0.0	1.37	0.000	2.85	2.20	2.19
III-43	9	26	0.42	193.7	52.1	4.7	0.27	0.024	3.89	3.86	3.82
III-44	12	35	0.71	570.6	160.4	16.0	0.28	0.028	4.14	4.21	4.10
III-45	7	21	0.44	297.6	76.6	7.0	0.26	0.023	4.24	4.15	4.19
III-46 ³	7	21	0.29	58.6	16.2	2.3	0.28	0.039	3.57	3.44	3.56
III-47	10	28	0.54	661.1	175.4	6.0	0.27	0.009	4.38	4.38	4.32
III-48	11	31	0.63	272.6	83.9	3.4	0.31	0.012	3.97	3.95	3.92
III-49	9	26	0.49	577.6	146.6	16.5	0.25	0.029	4.34	4.34	4.30
III-50	7	20	0.48	117.5	17.2	0.0	0.15	0.000	3.66	3.78	3.73
III-51	9	25	0.69	204.5	48.2	5.2	0.24	0.026	3.89	3.91	3.80
III-52	6	18	0.58	416.1	70.9	7.3	0.17	0.018	4.36	4.37	4.31
III-53	6	17	0.50	276.1	46.9	1.9	0.17	0.007	4.21	4.21	4.14
III-54	8	23	0.53	255.6	49.6	4.9	0.19	0.019	3.99	4.05	4.02
III-55	7	22	0.64	372.1	77.6	7.0	0.21	0.019	4.23	4.24	4.20
IV-2	231	669	0.63	11836.6	13953.0	-	1.18	-	4.35	4.25	4.26
IV-4	138	402	0.52	5635.6	5881.0	-	1.04	-	4.21	4.15	4.17
IV-5 ⁴	144	419	0.84	2587.0	1372.9	-	0.53	-	3.56	3.79	3.58
IV-6	167	483	0.88	7761.1	7299.2	-	0.94	-	4.22	4.21	4.19

IV-7	159	462	0.62	7475.1	8078.3	-	1.08	-	4.28	4.21	4.19
IV-8	124	360	0.72	8970.3	9838.3	-	1.10	-	4.49	4.40	4.37
IV-9	128	371	0.61	8632.3	8604.5	-	1.00	-	4.41	4.37	4.20
IV-10	110	318	0.64	2099.8	2017.6	-	0.96	-	3.86	3.82	3.53
IV-11	207	601	0.89	8268.1	7761.8	-	0.94	-	4.14	4.14	4.03
IV-12	170	494	0.73	8242.1	9174.3	-	1.11	-	4.31	4.22	4.22
IV-13	103	298	0.51	4361.8	3969.3	-	0.91	-	4.19	4.17	4.17
IV-14 ^d	115	334	0.55	1287.1	1602.8	-	1.25	-	3.74	3.59	3.52
IV-15	105	303	0.50	5365.8	4704.3	-	0.88	-	4.25	4.25	3.94

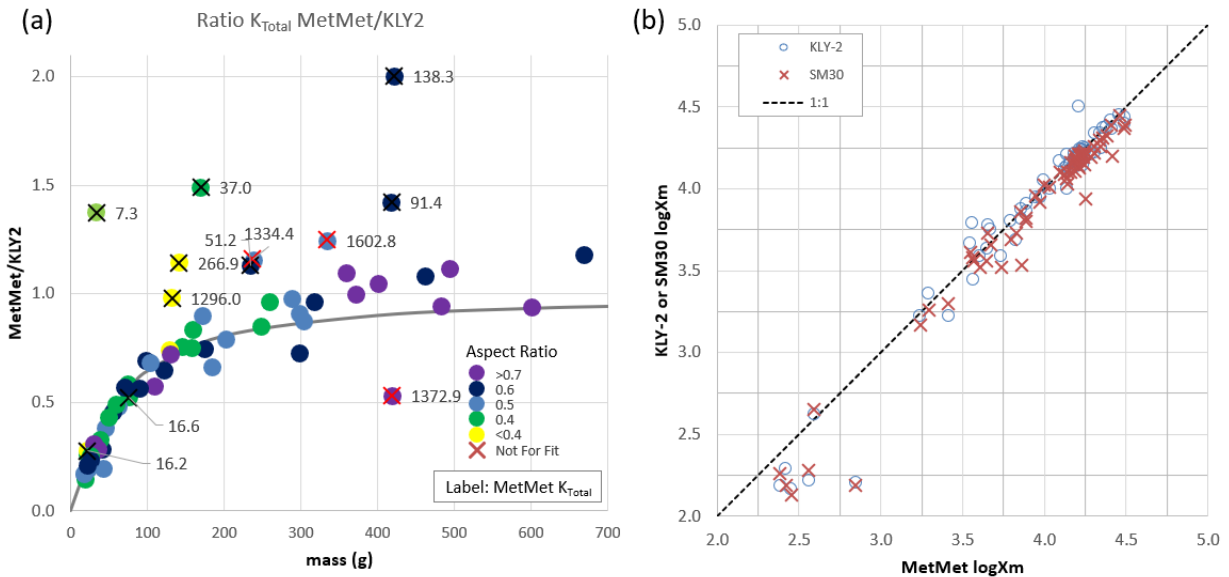


Figure S1. (a) Apparent K_{Total} of basalt pebbles measured by susceptibility normalized by the actual K_{Total} by KLY-2. The colors indicate the aspect ratio of the shape given by $(\text{minor axis})/(\text{major axis} \cdot \text{intermediate axis})^{0.5}$. The label numbers are the apparent K_{Total} by MetMet. The cross symbols indicate the samples rejected for the β value calculation (solid curve). The red cross symbols indicate the other rejected samples. (b) $\log \chi_m$ values for the basalt pebbles measured by MetMet versus KLY-2 and SM30.

We used a L5 chondrite (El Médano 029) and a H4 chondrite (San Juan 038), and a banded iron formation (BIF) sample described in Launay et al. (2018) for the repeated measurements with the different Meteorite meter units (Table S4, Fig. S2). The raw data is available in the separated csv file (ShippingTest.csv).

Table S4 List of standard samples for testing the individual Meteorite meter units

Name	Mass (g)
L5 ELM29	98
H5 SJ038	55
BIF	332

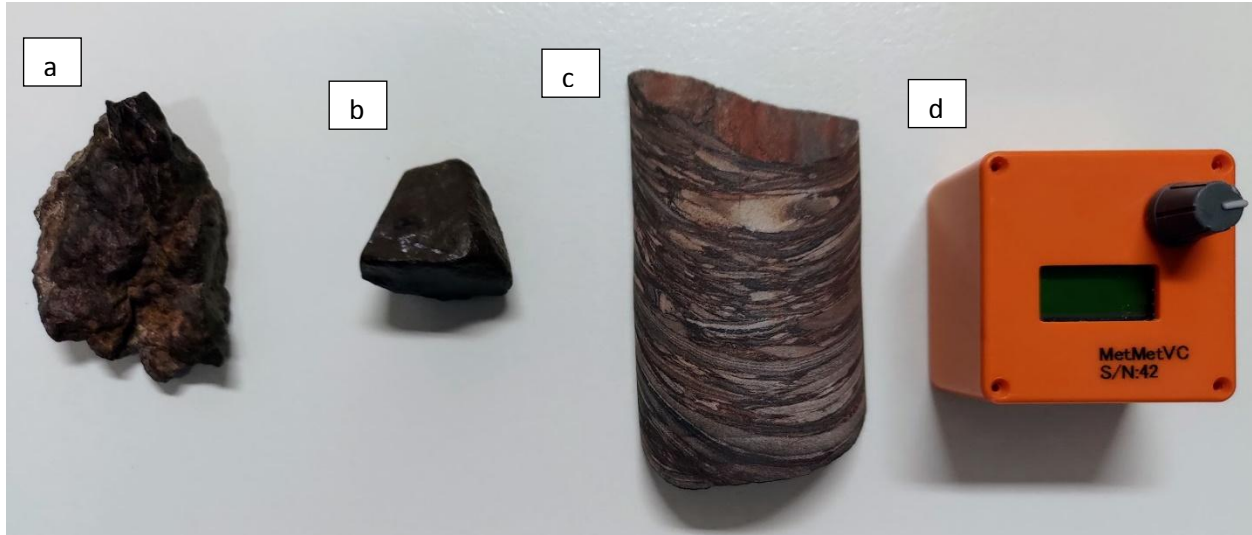


Figure S2. Photographs of the standard samples (a) El Médano 029 L5 chondrite, (b) San Juan 038 H5 chondrite, (c) banded iron formation (BIF), and (d) the Meteorite meter for scale (approx. 5 cm).

Launay N., Quesnel Y., Rochette P., and Demory F. 2018. *Iron Formations as the Source of the West African Magnetic Crustal Anomaly*. *Front. Earth Sci.* 6:32. doi: 10.3389/feart.2018.00032

Lecoanet H., Leveque F., and Segura S., 1999. Magnetic susceptibility in environmental application: comparison of field probes, *Phys. Earth planet Inter.*, 115, 191-204.

S3. Detection limit of the MetMet

The minimum mass of the function of the $\log\chi_m$ calculation of the MetMet is 5 g. This lower limit is reasonable for the basic use of the MetMet. However, the advance user of MetMet occasionally faces the problem of samples smaller than 5 g. This is problematic since the mass factor $1/\beta(m)$ of eq. (4) changes significantly below 10 g. Although the user can manually calculate the actual $\log\chi_m$ value by means of eq. (4), it is possible to estimate the $\log\chi_m$ for small mass less than 10 g without calculator. If we consider a small sample with susceptibility of $\log\chi_{m_1}$ whose mass is m_1 , and the $\log\chi_{m_2}$ is the values displays on the MetMet for the discrete mass input $m_2 = 10, 20, 30, \dots, 100$, a simple manipulation of eq. (4) show the relation of $\log\chi_{m_1} = \log\chi_{m_2} + \log_{10} \frac{\beta(m_2)}{\beta(m_1)}$. The $\beta(m)$ is a quasi-linear function for small mass (Fig. 2b), being $\log_{10} \frac{\beta(m_2)}{\beta(m_1)} \cong \log_{10} \frac{m_2}{m_1} = 1$ when $m_2 = 10m_1$. Finally, we can use the simple approximation of $\log\chi_{m_1} \cong \log\chi_{m_2} + 1$ (if $m_2 = 10m_1 < 100$ g). To measure the small sample ($m_1 = 6$ g), for example, we add 1 to the $\log\chi_m$ value for $m_2 = 60$ g shown on the MetMet. This simple approximation works well when the mass is below 10 g (Fig. S3).

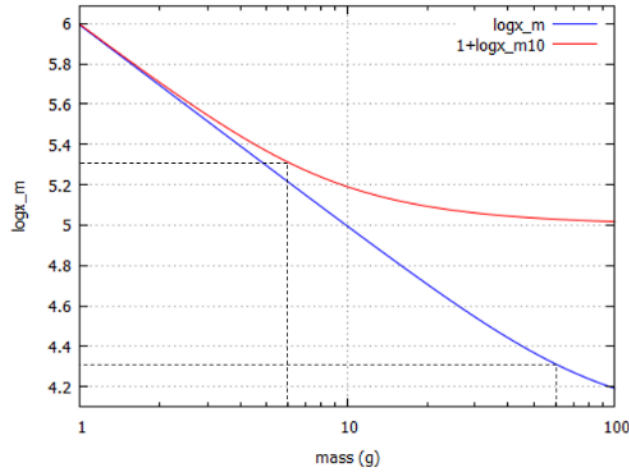


Figure S3. Mass-calibrated $\log\chi_m$ values for $\log\chi_m = 4$ at the infinite volume using the actual $\beta(m)$ function (blue line) and the simple linear approximation (red line). The dashed lines explain the case for 6 g by means of $\log\chi_m$ value for 60 g.

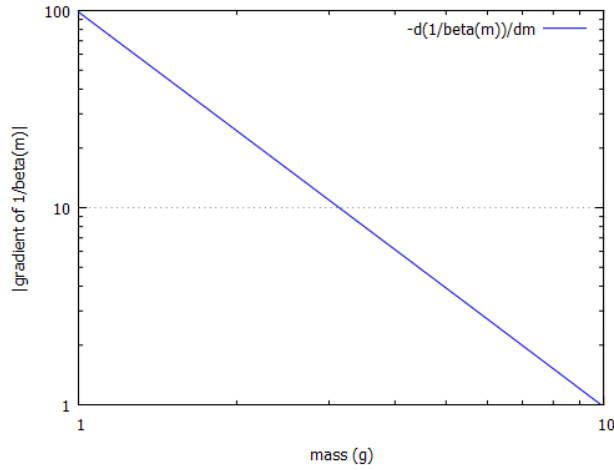


Figure S4. Absolute value of the gradient of the mass-calibration factor $1/\beta(m)$ as a function of mass.

Mathematically, one can calculate the $\log\chi_m$ value for very small samples using eq. (4). However, there are two limitations related to the sensitivity. The first is the excessive sensitivity on the mass below 5 g (Fig. S3), where the change in K value is larger than 10 per 1 g (Fig. S4). Due to this, we need to keep the possible large error for the small samples that is much smaller than the pick-up coil. The second limitation is the sensitivity of the instrument itself. As we discussed in the main text (§3.2), there are theoretical detection limits due to the resolution of the frequency counter. The acquisition period of the MetMet is 4 seconds; for the nominal frequency of 100 kHz, the resolution corresponding to the 1 count is $(4 \times 100 \times 10^3)^{-1} = 2.5 \times 10^{-6}$, which corresponding to $\log\chi_m = 1.25$. The thermal drift can rise this limit to $\log\chi_m = 1.86$. Those two lower limits are, indeed, visible in the histogram of background measurements (Fig. 3); $\log\chi_m$ is 1 by the specification if $f_{sample} = f_{air}$, $\log\chi_m$ is 1.25 if f_{sample} changes 1 count from f_{air} , and the nominal thermal drift of $\log\chi_m = 1.86$.

In addition to this limitation of the digital counter circuitry, the MetMet has other limitations due to the analog circuitry and magnetism. The actual increase of the magnetic field crossing the pick-up coil (self-inductance) is related to the total magnetic susceptibility (K_{Total} in m^3) that is calculated by

$10^{\log \chi_m} \cdot m$, where m is mass in kg. We compare the K_{Total} measured by MetMet with that measured by KLY-2 for 144 meteorites. A simple plot (Fig. S4a) indicate a good linear relationship in K_{Total} . The trend is about on the 1:1 line, though MetMet slightly overestimates the susceptibility. This departure from 1:1 line is very visible when we plot $(\text{MetMet } \log \chi_m) / (\text{KLY-2 } \log \chi_m)$ ratio as a function of K_{Total} . This $\log \chi_m$ ratio starts to depart from the trend line when the actual K_{Total} values by KLY-2 is smaller than $100 \times 10^{-9} \text{ m}^3$ (Fig. S5b). The apparent K_{Total} measured by MetMet has a clear cut-off at $10 \times 10^{-9} \text{ m}^3$ (Fig. S4c). These results indicate that the detection limit of MetMet is defined by K_{Total} and it is $10 \times 10^{-9} \text{ m}^3$ (Fig. S4a and S4c). This means that the actual detection limit is not defined by the mass; a small mass of the strongly susceptible materials (e.g., iron) can make a strong K_{Total} beyond this limit, whereas a large mass is needed for weakly susceptible materials (e.g., limestone) to obtain a reliable measurement. For information, the 5 g and $K_{Total} = 10 \times 10^{-9} \text{ m}^3$ limits correspond to $\log \chi_m = 3.6$, which is lower than the susceptibility of most meteorites (Fig. 4). The advanced users can calculate K_{Total} to correct the measured $\log \chi_m$ value by means of the fitting curve of Fig. S4c. The example of this correction is demonstrated by the comparison with the $\log \chi_m$ value measured by SM30 (Fig. S6). The amount of departures from 1:1 line is the function of the K_{Total} , and the correction using the fitting curve shown in (Fig. S5c) is very effective.

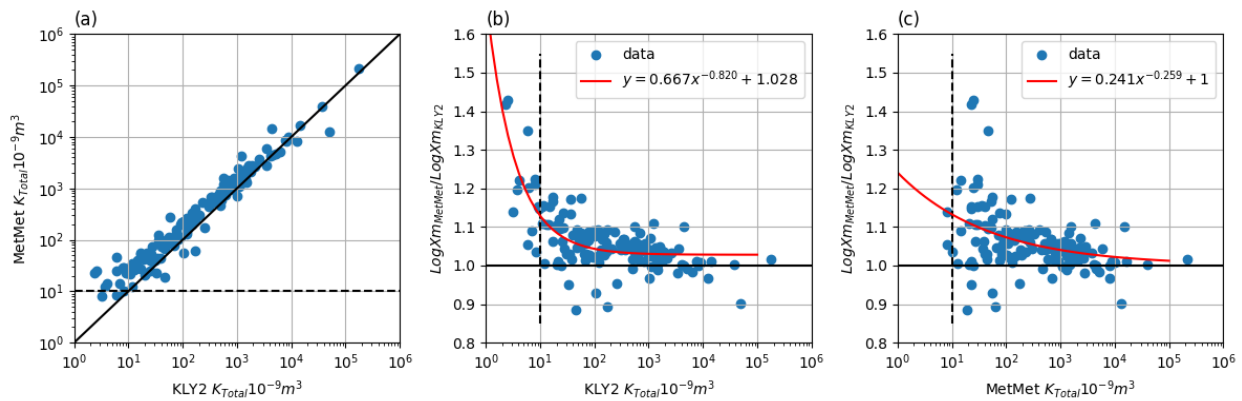


Figure S5. (a) Total magnetic susceptibility measured by the MetMet versus KLY-2. (b) The ratio of $\log \chi_m$ measured by MetMet and KLY-2 as a function of the actual K_{Total} measured by KLY-2. (c) The same ratio as a function of the K_{Total} measured by MetMet. The dashed black lines correspond to $K_{Total} = 10 \times 10^{-9} \text{ m}^3$ of MetMet.

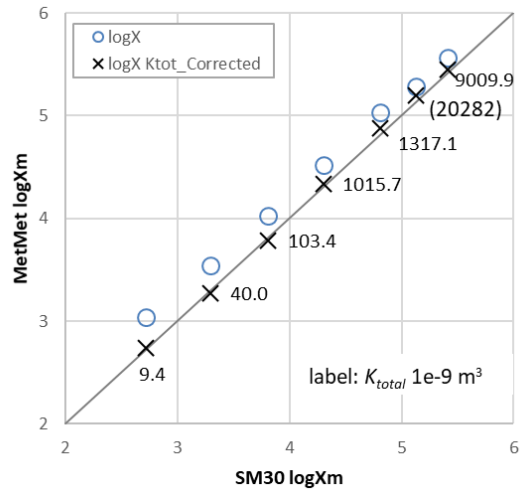


Figure S6. $\log X_m$ values for meteorites measured by MetMet and SM30. The label shows K_{Total} measured by KLY-2. The value in parenthesis is K_{Total} by MetMet due to the lack of measurement by KLY-2.

S4. All PCA results

Some meteorites belong to two categories (e.g. Achondrites and Metal Dominated) in the statistics; Category 1 and 2 indicates the categories of meteorites. The set of several meteorite groups (e.g. All Achondrites = all meteorites in Achondrites category) is in italic. The number of the samples N , mean and standard deviation values of C-index and $\log\chi_m$, the semidiameters of the confidence ellipse (a , b), the slope of the first principal component are shown. The estimate of a covariance matrix using *numpy.cov* method for the data [C-Index array, $\log\chi_m$ array]^T, eigen value and eigen vector of the covariance matrix using *scipy.linalg.eig* method, and explained variance ratio of PC₁ are shown. The covariance matrix is in order of [Var(C-index), Cov(C-index, $\log\chi_m$)], [Cov(C-index, $\log\chi_m$), Var($\log\chi_m$)]. Var. = Variance, Cov. = Covariance, S.D. = standard deviation, EVR= explained variance ratio, OCs = Ordinary Chondrites, W_OC = weathered ordinary chondrites, *AcaLod* = acapulcoite + lodranite, *BraUre* = brachinite + ureilite, *HED* = howardite + eucrite + diogenite. ¹Excluding iron meteorites and pallasites.

Table S5 The all results of principal component analysis.

Category 1	Category 2	Group	N	Mean C-Index	Mean $\log\chi_m$	S.D. C-index	S.D. $\log\chi_m$	Slope	a	b	Covariance	Eigen Value of Cov.	Eigen Vector of Covariance	EVR PC ₁
Magnetite Dominated	Magnetite Dominated	<i>All Magnetite Dominated</i>	29	2.01	4.40	0.23	0.59	3.00	1.21	0.25	[0.0527, 0.1091], [0.1091, 0.3437]	[0.3801, 0.0163]	[-0.3163, -0.9487], [-0.9487, 0.3163]	0.96
Magnetite Dominated	Non OCs	CV	16	1.93	4.12	0.22	0.62	3.40	1.27	0.23	[0.0463, 0.1089], [0.1089, 0.3839]	[0.4159, 0.0142]	[-0.2825, -0.9593], [-0.9593, 0.2825]	0.97
Magnetite Dominated	Non OCs	CK	9	2.16	4.84	0.07	0.13	6.22	0.26	0.14	[0.0053, 0.0019], [0.0019, 0.0168]	[0.0172, 0.005]	[-0.1588, -0.9873], [-0.9873, 0.1588]	0.78
Magnetite Dominated	Non OCs	CM	2	1.85	4.16	0.49	0.41	-	-	-	[0.245, 0.205], [0.205, 0.1716]	-	-	-
Magnetite Dominated	Non OCs	CVox	2	2.20	4.88	0.28	0.06	-	-	-	[0.08, 0.0165], [0.0165, 0.0034]	-	-	-
Metal Dominated	Metal Dominated	<i>All Metal Dominated</i>	108	2.19	4.25	0.68	0.85	1.31	2.07	0.56	[0.4595, 0.495], [0.495, 0.7303]	[1.1081, 0.0817]	[-0.6067, -0.7949], [-0.7949, 0.6067]	0.93
Metal Dominated	Metal Dominated	eucrite	23	1.71	3.29	0.27	0.37	2.59	1.49	0.98	[0.073, 0.0274], [0.0274, 0.1333]	[0.1439, 0.0624]	[-0.3607, -0.9327], [-0.9327, 0.3607]	0.70
Metal Dominated	Metal Dominated	diogenite	11	1.61	3.45	0.23	0.28	-2.72	1.13	0.87	[0.0529, -0.0112],	[0.0833, 0.0488]	[0.3456, -0.9384],	0.63

Metal Dominated	Non OCs	CO	11	2.08	4.52	0.20	0.36	2.98	0.74	0.34	[-0.0112, 0.0792] [0.0416, 0.0336], [0.0336, 0.1305] [0.0236, 0.0145], [0.0145, 0.0119]	[0.1417, 0.0304]	[-0.9384, -0.3456] [-0.3179, -0.9481], [-0.9481, 0.3179] [0.8288, -0.5595], [0.5595, 0.8288]	0.82
Metal Dominated	OCs	L	9	2.74	4.92	0.15	0.11	0.68	0.36	0.09	[0.0292, 0.0074], [0.0074, 0.0234] [0.039 , 0.0308], [0.0308, 0.0606]	[0.0334, 0.0022]	[0.8249, -0.5653], [0.5653, 0.8249] [-0.5791, -0.8153], [-0.8153, 0.5791]	0.94
Metal Dominated	OCs	H	7	3.11	5.36	0.17	0.15	0.69	0.36	0.27	[0.3762, 0.171], [0.171 , 0.1097]	[0.0343, 0.0184]	[0.8249, -0.5653], [0.5653, 0.8249] [-0.5791, -0.8153], [-0.8153, 0.5791]	0.65
Metal Dominated	OCs	LL	7	1.77	3.87	0.20	0.25	1.41	0.56	0.26	[0.3762, 0.171], [0.171 , 0.1097]	[0.0825, 0.0171]	[0.8985, -0.4389], [0.4389, 0.8985] [0.9004, 0.435], [-0.435 , 0.9004]	0.83
Metal Dominated	Achondrites	mesosiderite	7	3.34	5.37	0.61	0.33	0.49	1.33	0.32	[0.2817, -0.118], [-0.118 , 0.0944]	[0.4597, 0.0262]	[0.9004, 0.435], [-0.435 , 0.9004]	0.95
Metal Dominated	Achondrites	iron meteorites	6	4.58	5.13	0.53	0.31	-0.48	1.14	0.38	[0.04 , 0.0135], [0.0135, 0.0645]	[0.3387, 0.0374]	[0.9004, 0.435], [-0.435 , 0.9004]	0.90
Metal Dominated	Achondrites	lunar meteorites	5	1.60	3.48	0.20	0.25	2.26	0.52	0.36	[0.2669, 0.0229], [0.0229, 0.0141]	[0.0705, 0.034]	[0.9004, 0.435], [-0.435 , 0.9004]	0.67
Metal Dominated	Achondrites	pallasite	5	4.22	5.61	0.52	0.12	0.09	1.02	0.22	[0.0892, 0.0651], [0.0651, 0.0944] [0.0292, 0.0589], [0.0589, 0.1207] [0.0667, 0.0734], [0.0734, 0.0891]	[0.269, 0.0121]	[0.996 , -0.0894], [0.0894, 0.996]	0.96
Metal Dominated	Metal Dominated	acapulcoite	4	2.68	5.19	0.30	0.31	1.04	1.56	0.64	[0.0892, 0.0651], [0.0651, 0.0944] [0.0292, 0.0589], [0.0589, 0.1207] [0.0667, 0.0734], [0.0734, 0.0891]	[0.1569, 0.0267]	[-0.6927, -0.7212], [-0.7212, 0.6927] [-0.4396, -0.8982], [-0.8982, 0.4396]	0.85
Metal Dominated	Metal Dominated	ureilite	4	2.03	4.54	0.17	0.35	2.04	1.52	0.07	[0.0667, 0.0734], [0.0734, 0.0891]	[0.1495, 0.0003]	[-0.4396, -0.8982], [-0.8982, 0.4396]	1.00
Metal Dominated	Non OCs	CVred	4	2.00	4.42	0.26	0.30	1.16	0.77	0.12	[0.0667, 0.0734], [0.0734, 0.0891]	[0.1522, 0.0036]	[-0.6515, -0.7587], [-0.7587, 0.6515]	0.98
Metal	Metal	howardite	3	1.77	3.86	0.21	0.34	1.69	1.55	0.25	[0.0433, 0.0433]	[0.1549, 0.1549]	[-0.5097, 0.5097]	0.97

Dominated	Dominated										0.0661], [0.0661, 0.1157]	0.0042]	-0.8603], [-0.8603, 0.5097]	
Metal Dominated	Non OCs	EL	3	3.47	5.55	0.74	0.24	0.22	1.48	0.35	[0.5433, 0.1141], [0.1141, 0.057]	[0.5687, 0.0315]	[0.9761, -0.2175], [0.2175, 0.9761]	0.95
Metal Dominated	Metal Dominated	brachinite	2	1.85	3.94	0.07	0.59	-	-	-	[0.005 , 0.0416], [0.0416, 0.3458]	-	-	-
Metal Dominated	Metal Dominated	eucrite (metal-rich)	2	1.70	4.23	0.42	0.24	-	-	-	[0.18 , -0.1034], [-0.1034, 0.0594]	-	-	-
Metal Dominated	Non OCs	CR	2	2.60	5.17	0.00	0.02	-	-	-	[0. , 0.], [0. , 0.0005]	-	-	-
Metal Dominated	Achondrites	winonaite	1	4.00	5.55	-	-	-	-	-	-	-	-	-
Metal Dominated	Metal Dominated	H/L	1	2.70	5.23	-	-	-	-	-	-	-	-	-
Metal Dominated	Metal Dominated	Iodranite	1	2.30	4.72	-	-	-	-	-	-	-	-	-
Metal Dominated	Non OCs	CH	1	2.90	5.40	-	-	-	-	-	-	-	-	-
Non OCs	Non OCs	<i>All Non OCs</i>	59	2.11	4.40	0.44	0.64	1.63	2.88	1.02	[0.1957, 0.2092], [0.2092, 0.4089]	[0.537, 0.0675]	[-0.5224, -0.8527], [-0.8527, 0.5224]	0.89
OCs	OCs	<i>All OCs</i>	23	2.56	4.73	0.58	0.63	1.10	3.34	0.42	[0.3339, 0.3541], [0.3541, 0.4007]	[0.7229, 0.0117]	[-0.6731, -0.7396], [-0.7396, 0.6731]	0.98
Pyrrhotite dominated	Pyrrhotite dominated	<i>All Pyrrhotite dominated</i>	14	1.87	3.62	0.21	0.19	0.10	0.84	0.75	[0.0453, 0.0008], [0.0008, 0.0365]	[0.0454, 0.0365]	[0.9955, -0.0947], [0.0947, 0.9955]	0.55
Pyrrhotite dominated	Non OCs	R	9	1.82	3.59	0.24	0.13	-0.01	0.48	0.25	[0.0594, -0.0003], [-0.0003, 0.0157]	[0.0594, 0.0157]	[1. , 0.0062], [-0.0062, 1.]	0.79
Pyrrhotite dominated	Achondrites	shergottite	5	1.96	3.69	0.11	0.28	-8.31	0.56	0.22	[0.013, -0.008], [-0.008 , 0.0789]	[0.0799, 0.012]	[0.1195, -0.9928], [-0.9928, -0.1195]	0.87
Achondrites	Achondrites	<i>All Achondrites</i>	77	2.35	4.08	1.06	0.93	0.86	5.32	1.63	[1.1304, 0.821],	[1.8331, 0.1712]	[0.7597, -0.6502],	0.91

Achondrites	Achondrites	<i>HED</i>	37	1.69	3.38	0.25	0.37	4.32	0.73	0.48	[0.821 , 0.8739]	[0.6502, 0.7597]	
											[0.0645, 0.0173],	[-0.2257, -0.9742],	0.70
											[0.0173, 0.1353]	[-0.9742, 0.2257]	
Achondrites	Achondrites	<i>BraUre</i>	6	1.97	4.34	0.16	0.49	3.25	1.00	0.13	[0.0267, 0.0715],	[-0.2945, -0.9557],	0.98
											[0.0715, 0.2368]	[-0.9557, 0.2945]	
Achondrites	Achondrites	<i>AcaLod</i>	5	2.60	5.10	0.31	0.34	1.13	0.86	0.28	[0.095 , 0.0845],	[-0.662 , -0.7495],	0.90
											[0.0845, 0.116]	[-0.7495, 0.662]	
Terrestrial	Terrestrial	basalt	18	1.03	3.90	0.86	0.54	0.23	3.42	2.05	[0.7313, 0.108],	[0.9735, -0.2285],	0.74
											[0.108 , 0.2963]	[0.2285, 0.9735]	
Terrestrial	Terrestrial	granite	4	0.33	1.90	0.65	1.18	1.86	5.25	0.66	[0.4225, 0.7321],	[-0.4745, -0.8802],	0.98
											[0.7321, 1.3859]	[-0.8802, 0.4745]	
Terrestrial	Terrestrial	marcassite	4	0.18	1.88	0.35	0.65	2.46	2.73	0.99	[0.1225, 0.1458],	[-0.3762, -0.9266],	0.88
											[0.1458, 0.4225]	[-0.9266, 0.3762]	
Terrestrial	Terrestrial	rhyolitic ignimbrite	4	0.80	2.28	0.63	0.37	0.57	2.85	0.48	[0.4 , 0.2193],	[0.8688, -0.4952],	0.97
											[0.2193, 0.1402]	[0.4952, 0.8688]	
Terrestrial	Terrestrial	BIF	3	0.57	5.76	0.98	0.04	-0.02	3.86	0.14	[0.9633, -0.0198],	[0.9998, 0.0206],	1.00
											[-0.0198, 0.0016]	[-0.0206, 0.9998]	
Terrestrial	Terrestrial	steel	3	5.27	5.88	1.27	0.21	0.17	5.06	0.00	[1.6133, 0.2713],	[0.9862, -0.1659],	1.00
											[0.2713, 0.0456]	[0.1659, 0.9862]	
Terrestrial	Terrestrial	gneiss	2	0.54	3.07	0.76	1.07	-	-	-	[0.5724, -0.8084],	-	-
											[-0.8084, 1.1416]	-	-
Terrestrial	Terrestrial	limestone	2	0.75	1.92	0.49	0.52	-	-	-	[0.245, 0.259],	-	-
											[0.259 , 0.2738]	-	-
Terrestrial	Terrestrial	serpentinite	2	0.12	4.43	0.17	0.29	-	-	-	[0.0288, -0.0492],	-	-
											[-0.0492, -0.0492],	-	-

											0.0841]			
Terrestrial	Terrestrial	aluminum	1	6.00	6.00	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	andesite	1	0.00	4.21	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	calcite	1	0.00	1.00	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	coal	1	0.00	1.00	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	gabbro	1	0.72	2.56	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	granulite	1	0.00	2.94	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	microdiorite	1	0.00	4.21	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	pyrite	1	0.00	1.00	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	pyroxenite	1	0.72	2.57	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	quartz	1	0.00	1.00	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	rhyolite	1	1.70	2.34	-	-	-	-	-	-	-	-	-
Terrestrial	Terrestrial	tourmaline	1	0.00	2.51	-	-	-	-	-	-	-	-	-
W_OC	W_OC	<i>All Weathered H</i>	81	2.70	5.12	0.40	0.22	0.42	1.69	0.63	[0.1615, 0.0573], [0.0573, 0.0498]	[0.1856, 0.0256]	[0.9214, -0.3886], [0.3886, 0.9214]	0.88
W_OC	W_OC	H, W4	6	2.17	4.75	0.18	0.08	0.20	0.70	0.31	[0.0307, 0.0049], [0.0049, 0.0071]	[0.0317, 0.0061]	[0.9804, -0.1972], [0.1972, 0.9804]	0.84
W_OC	W_OC	H, W3	21	2.43	4.96	0.29	0.16	0.10	1.13	0.63	[0.0824, 0.0057], [0.0057, 0.0266]	[0.083, 0.026]	[0.9949, -0.101], [0.101 , 0.9949]	0.76
W_OC	W_OC	H, W2	30	2.76	5.14	0.35	0.16	0.15	1.40	0.59	[0.1246, 0.0152], [0.0152, 0.0249]	[0.1268, 0.0226]	[0.9891, -0.1471], [0.1471, 0.9891]	0.85
W_OC	W_OC	H, W1	20	3.01	5.29	0.29	0.13	0.24	1.17	0.43	[0.084 , 0.0177], [0.0177, 0.016]	[0.0883, 0.0117]	[0.9714, -0.2375], [0.2375, 0.9714]	0.88
W_OC	W_OC	H, W0	3	3.13	5.52	0.21	0.05	0.17	0.83	0.13	[0.0433, 0.0072], [0.0072, 0.0023]	[0.0446, 0.001]	[0.9858, -0.1682], [0.1682, 0.9858]	0.98
W_OC	W_OC	<i>All Weathered L</i>	61	2.51	4.72	0.37	0.23	0.50	1.61	0.63	[0.1398, 0.057], [0.057 , 0.0544]	[0.1683, 0.0259]	[0.8944, -0.4474], [0.4474, 0.8944]	0.87

W_OC	W_OC	L, W5	1	2.30	4.64	-	-	-	-	-	-	-	-	-
W_OC	W_OC	L, W4	3	2.17	4.40	0.12	0.23	-3.03	0.93	0.37	[0.0133, -0.014], [-0.014, 0.051]	[0.0556, 0.0087]	[0.3134, -0.9496], [-0.9496, -0.3134]	0.86
W_OC	W_OC	L, W3	21	2.39	4.64	0.41	0.19	0.27	1.66	0.65	[0.1683, 0.0378], [0.0378, 0.0372]	[0.1784, 0.0271]	[0.9659, -0.2588], [0.2588, 0.9659]	0.87
W_OC	W_OC	L, W2	11	2.47	4.63	0.49	0.29	0.48	2.10	0.74	[0.2402, 0.0973], [0.0973, 0.0818]	[0.2864, 0.0356]	[0.9032, -0.4293], [0.4293, 0.9032]	0.89
W_OC	W_OC	L, W1	16	2.67	4.87	0.24	0.12	0.38	1.01	0.35	[0.0581, 0.0195], [0.0195 , 0.0153]	[0.0657, 0.0078]	[0.9032, -0.4293], [0.4293, 0.9032]	0.89
W_OC	W_OC	L, W0	2	2.68	4.90	0.04	0.11	-	-	-	[0.0013, -0.0039], [-0.0039, 0.0123]			
W_OC	W_OC	All Weathered LL	24	1.80	3.99	0.33	0.29	0.60	1.36	1.04	[0.1065, 0.0224], [0.0224, 0.0829]	[0.1201, 0.0693]	[0.8559, -0.5171], [0.5171, 0.8559]	0.63
W_OC	W_OC	LL, W5	1	1.30	3.88	-	-	-	-	-				
W_OC	W_OC	LL, W4	4	2.05	4.01	0.17	0.48	3.44	1.97	0.42	[0.03 , 0.064], [0.064 , 0.2315]	[0.2502, 0.0114]	[-0.2792, -0.9602], [-0.9602, 0.2792]	0.96
W_OC	W_OC	LL, W3	4	1.92	4.14	0.39	0.25	0.49	1.70	0.70	[0.1558, 0.0614], [0.0614, 0.0618]	[0.1861, 0.0315]	[0.8967, -0.4427], [0.4427, 0.8967]	0.86
W_OC	W_OC	LL, W2	4	1.68	3.88	0.39	0.44	-2.06	1.79	1.49	[0.1558, -0.0246], [-0.0246, 0.1945]	[0.2064, 0.1439]	[0.4366, -0.8996], [-0.8996, -0.4366]	0.59
W_OC	W_OC	LL, W1	11	1.78	4.00	0.32	0.22	0.36	1.32	0.78	[0.1036, 0.0232], [0.0232, 0.0478]	[0.112, 0.0395]	[0.9406, -0.3396], [0.3396, 0.9406]	0.74
W_OC	W_OC	LL, W0	1	1.90	4.14	-	-	-	-	-				

S5. All raw data tables

All raw data used to conduct the principal component analyses. The detail explanation is available in §S1.

Table S6 Raw data of meteorites.

official name	mass	C index	logX	group	Class	Type	W	logX_ KLY2	logX_ SM30
Akka 001	4.34	2.6	5.429775823	acapulcoite	acapulcoite			5.11	
Al Haggounia 005	18.97	1.9	2.817395809	euclite	euclite			2.8	
Ardestan	17.07	3.9	5.47	iron	iron				
Awsserd	16.17	1.7	3.469266247	R4	R	4			
Aydar 001	12.24	2.3	4.743495181	acapulcoite	acapulcoite			4.44	
Aydar 002	21.29	1.8	3.03	euclite	euclite			2.63	
Aydar 008	14.46	2.3	4.719012291	lodranite	lodranite			4.49	
Calama 001	12.32	2	4.492695917	ureilite	ureilite				
Calama 076	16.3	1.7	3.250852661	diogenite	diogenite			2.94	
Calama 138	13.17	1.8	4.659051675	CO3	CO	3		4.45	
Caleta el Cobre 024	15.37	2.9	5.59	EL6	EL	6		5.36	
Caleta el Cobre 028	65	3.2	5.297120408	EL6	EL	6		5.88	
Catalina 005	216.6	3.2	5.26	H4 W1	H	4	1	5.24	
Catalina 037	10.16	1.8	4.063669668	ureilite	ureilite				
El Medano 103	50.49	1.9	4.07	LL6 W1	LL	6	1	4	
El Medano 227	74.56	1.5	3.37	LL6 W2	LL	6	2	3.53	
El Medano 300	50	4.8	4.91	iron	iron				
El Medano 350	110	2.3	4.107416596	euclite	euclite			3.79	
El Medano 444	24.99	4.3	5.77	EL6	EL	6		5.24	
El Medano 73	59.36	1.6	3.89	LL6 W3	LL	6	3	3.92	
Famenin	10.47	2.7	5.225714731	H/L3 fall	H/L	3	0	5.09	
Ghardaia 002	17.54	1.9	3.75	lunar (feldsp. breccia)	lunar			3.31	
Gibeon	300	5	5.29	iron	iron				
Gibeon	300	5.2	4.83	iron	iron				5.13
Hassi Arsane 002	13.7	1.5	2.780134056	euclite	euclite			2.64	
Imilac	18.42	4.1	5.40986359	pallasite	pallasite				
Imilac	61	5.1	5.72	pallasite	pallasite				
Jdiriya 002	8.6	1.7	3.156615731	euclite	euclite			2.64	
Lahmada 021	19.8	2.3	4.929282031	CO3	CO	3		4.82	
Lahmada 046	12.82	1.5	3.286610592	lunar (feldsp. breccia)	lunar			2.3	
Lahmada 047	9.92	1.7	3.358977798	lunar (feldsp. breccia)	lunar			2.37	
Lahmada 048	9.43	2.1	4.7408323	ureilite	ureilite			4.49	
Los Vientos 055	8.62	2	4.205612208	CO3	CO	3		3.95	
Los Vientos 099	67	2.9	5.12	H3 W1	H	3	1	5.06	

Los Vientos 122	1138	3.26	5.28	H5 W1	H	5	1	5.19
Los Vientos 200	18	2.9	5.4	CH	CH			5.4
Los Vientos 290	17.28	2	4.244994817	howardite	howardite			4.07
Moshampa	16.32	1.9	4.13833	LL5 fall	LL	5	0	3.8
Murchison	12	1.5	3.867006426	CM2	CM	2		
NWA 10160	20	2	3.86	LL6 W1	LL	6	1	3.77
NWA 10163	13.12	1.8	3.04	euclite	euclite			2.49
NWA 10164	20.5	1.6	3.404616846	euclite	euclite			2.92
NWA 10381	5.95	1.7	3.61800398	howardite	howardite			3.01
NWA 10385	17.78	2.1	4.858871767	CO3	CO	3		4.74
NWA 10551	19	2.2	4.59	CK6	CK	6		4.52
NWA 10777	6.6	2.3	4.55	CV3	CV	3		4.4
NWA 10779	15	1.5	3.25	diogenite	diogenite			2.94
NWA 10781	18	1.9	3.1	diogenite	diogenite			3.26
NWA 11087	9.14	1.8	3.432315125	CV3	CV	3		3.43
NWA 11207	13.69	2.2	4.979447	CK5-an	CK	5		4.81
NWA 11346	7.64	2.2	4.452781148	CM-an	CM			4.09
NWA 11472	16.24	1.5	3.252424641	lunar	lunar			2.82
NWA 11533	15.75	2	4.843492325	CVox3	CVox	3		4.57
NWA 11535	21.88	2.3	4.950198731	CK6	CK	6		4.79
NWA 11537	12.39	2.3	4.983261748	CV3	CV	3		4.72
NWA 11543	20.49	2.2	4.585822601	CV3	CV	3		4.41
NWA 11545	21.16	1.9	3.710267012	CV3	CV	3		3.51
NWA 11546	12.76	2	4.65062451	CV3	CV	3		4.41
NWA 11589	11.36	1.9	4.246580644	CVred3	CVred	3		3.91
NWA 11749	18.61	2.1	3.193512926	euclite	euclite			2.64
NWA 11887	13	3.8	5.696626209	mesosiderite	mesosiderite			
NWA 11888	26.94	1.6	3.527507323	diogenite	diogenite			3.32
NWA 12329	17.17	2.2	4.645710938	CO3	CO	3		4.48
NWA 12333	18.35	2.1	3.622478325	R5	R	5		3.57
NWA 12334	31.36	1.7	3.58728099	R6	R	6		3.06
NWA 12467	8.7	1.4	4.404621509	euclite (metal-rich)	euclite (metal-rich)			4.08
NWA 12469	12.65	2.1	4.858341977	CV3	CV	3		4.59
NWA 12470	9.41	1.4	3.570748586	R3-5	R	5		3.09
NWA 12480	13.4	2.8	5.326625871	acapulcoite	acapulcoite			5.08
NWA 12482	9.77	2	3.75	R3	R	3		3.35
NWA 12523	18.17	1.7	4.166660285	CVred3	CVred	3		3.81
NWA 12524	21.1	2.1	4.786462262	CK5	CK	5		4.58
NWA 12550	2.42	2.1	3.773249891	shergottite	shergottite			3.46
NWA 12551	17.57	1.8	3.394919594	R3	R	3		3.34
NWA 12553	20.05	1.8	3.689982495	CV3	CV	3		3.38
NWA 12554	20.3	1.6	3.266752257	CV3	CV	3		3.13
NWA 12633	17.96	1.8	4.055594349	shergottite	shergottite			3.74
NWA 12730	20	4.1	5.607036804	mesosiderite	mesosiderite			5.8
NWA 12733	17.96	1.9	4.353594349	brachinite	brachinite			3.98
NWA 12916	49.6	4.6	4.83	iron	iron			

NWA 12958	22.75	1.4	3.564843848	euclite	euclite		3.46	
NWA 12959	24.98	1.9	4.326812677	CV3	CV	3	4.16	
NWA 12960	17.66	2	3.795748572	shergottite	shergottite		3.5	
NWA 12963	18.96	1.6	3.340619095	euclite	euclite			
NWA 12965	14.47	2	3.455716456	shergottite	shergottite		3.13	
NWA 13146	25.5	2	3.856252795	euclite	euclite		3.71	
NWA 13148	17.45	1.3	3.028832401	euclite	euclite		3.42	
NWA 13155	21.1	2.2	4.844462262	ureilite	ureilite		4.64	
NWA 13157	24.75	4.21	5.61	pallasite	pallasite			
NWA 13482	21.98	2.1	4.723283864	CK5-7	CK	7	4.48	
NWA 13486	3.55	1.9	3.36	shergottite	shergottite		2.95	
NWA 13490	20.4	2.5	5.034679192	CO3	CO	3	4.81	4.81
NWA 13491	23.4	2	4.54405581	CO3	CO	3	4.42	
NWA 13493	18.38	1.4	2.751785507	euclite	euclite		2.66	
NWA 13494	9.71	2	3.440207003	euclite	euclite		3.24	
NWA 13495	32.2	2.1	3.934570539	CO3	CO	3	3.71	
NWA 13503	20.8	2.2	4.880493109	CK3	CK	3	4.62	
NWA 13505	17.97	2.1	4.777358029	CK5	CK	5	4.6	
NWA 13705	22.9	1.7	3.836091751	diogenite	diogenite		3.53	
NWA 13706	18.94	2.1	4.443066037	Cvred3	CVred	3	4.09	
NWA 13710	24.29	1.6	3.214474236	diogenite	diogenite		2.79	
NWA 13712	14.83	1.2	3.701204306	diogenite	diogenite		3.26	
NWA 13713	14.37	4	5.550684323	winonaite	winonaite		5.64	
NWA 13720	19.8	3.9	5.614282031	pallasite	pallasite		5.62	
NWA 13723	17.28	2.1	4.912994817	CK6	CK	6	4.68	
NWA 13724	18.16	2.6	5.150893886	CR2	CR	2	4.93	
NWA 13833	13	1.7	3.678626209	diogenite	diogenite		4.12	
NWA 13834	16.56	2	3.512109407	diogenite	diogenite		3.2	
NWA 13835	18.12	1.6	3.401829635	euclite	euclite		2.52	
NWA 13839	19.9	3	5.278153792	acapulcoite	acapulcoite		5.11	
NWA 13886	21.22	1.8	4.525075356	CO3	CO	3	4.68	4.3
NWA 13887	18.82	2	4.021758136	CO3	CO	3	3.74	3.81
NWA 14096	17.43	2.1	4.955319899	CK5	CK	5	4.76	
NWA 14099	19.38	1.4	3.072346036	diogenite	diogenite		3.04	
NWA 14100	17.86	1.7	3.407965135	CV3	CV	3	3.11	
NWA 14101	14.66	1.6	3.794135232	R3-5	R	5	3.55	
NWA 14161	17.8	1.7	3.06639427	CV3	CV	3	3.06	
NWA 14252	19.5	1.3	3.459735374	euclite	euclite		3.73	
NWA 14253	19.07	1.6	3.316169728	euclite	euclite		3.12	
NWA 14283	17.9	4	5.45	iron	iron			
NWA 14418	34.35	1.7	3.385548179	euclite	euclite		3.22	
NWA 14530	23.7	1.7	2.95	euclite	euclite		2.66	
NWA 14541	9.96	3.9	5.636242329	mesosiderite	mesosiderite		5.08	
NWA 14542	21	2	3.541462384	R3	R	3	3.28	3.29
NWA 14700	18.45	2.6	5.182173526	CR2	CR	2	5.01	
NWA 14798	18.24	1.4	3.765028838	lunar	lunar		3.51	
				(feldsp.brecci				

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NWA 14799	9.72	3.8	5.676762949	pallasite	pallasite			5.72
NWA 14804	17.75	1.6	3.702589064	howardite	howardite			3.6
NWA 14805	20.37	2.1	4.341299982	CO3	CO	3		4.17
NWA 14808	12.6	2.4	4.926042676	CVox3 (OxB)	CVox	3		4.7
NWA 5436	22.77	2.3	4.83547578	CVred3	CVred	3		4.39
NWA 7199	5	3	5.33	H4 W1	H	4	1	5.35
NWA 7200	15	3.3	5.45	H5 W1	H	4	1	5.44
NWA 7201	15	2.6	4.79	L3 W1	L	3	1	4.74
NWA 7280	16.76	1.4	3.791996662	diogenite	diogenite			3.69
NWA 7283	5	1.6	3.9	LL6 W1	LL	6	1	3.79
NWA 7283	15	1.9	3.87	LL6 W1	LL	6	1	3.79
NWA 7386	11.68	2.7	5.307628945	mesosiderite	mesosiderite			4.96
NWA 7629	20	2.9	5.03	L5 W1	L	5	1	4.96
NWA 7756	23.39	1.8	3.09823449	euclite	euclite			2.53
NWA 7895	25	2.85	5.02	L6 W0/1	L	6	1	4.84
NWA 8274	25	2.9	5.03	L6 W1	L	6	1	4.94
NWA 8439	21.04	2.1	3.037661125	euclite	euclite			2.65
NWA 8477	20	2.7	4.84	L5 W1	L	5	1	4.84
NWA 8478	8.17	1.8	4.5257813	CV3	CV	3		3.85
NWA 8481	18.01	1.8	3.855414122	CV3	CV	3		3.82
NWA 8483	11.1	2.1	4.468546602	CV3	CV	3		4.13
NWA 8624	19.1	2.1	3.542504294	R5	R	5		3.39
NWA 8625	7.83	2.9	5.284157952	mesosiderite	mesosiderite			5.27
NWA 8626	17	2	4.06	euclite	euclite			3.95
				(metal-rich)	(metal-rich)			
NWA 8628	20	2.6	4.81	L4 W1	L	4	1	4.81
NWA13489	13.05	1.8	3.521978927	brachinite	brachinite			3.42
Oum Dreyga	11.47	2.9	5.47543399	H3-5 fall	H	5	0	
San Juan 031	36	2.5	4.88	L3 W0/1	L	3	0.5	4.98
San Juan 031	149.3	2.9	5.04	L3 W0/1	L	3	0.5	4.98
	8							
San Juan 116	27.7	2.6	4.731034205	mesosiderite	mesosiderite			4.62
Sueilila 003	17.81	1.9	4.583155732	CV3	CV	3		4.29
Sueilila 004	20	2.7	4.82	L6 W0	L	6	0	4.87
Taqtaq-e Rasoul	26.59	3.2	5.570911227	H5 fall	H	5	0	5.53
Vaca Muerta	1000	3.4	5.3	mesosiderite	mesosiderite			5.41
Zagora 002	23.6	1.8	4.015999366	euclite	euclite			3.76
Zagora 006	18.45	1.4	3.483173526	euclite	euclite			2.96

Table S7 Raw data of ordinary chondrites.

official name	mass	group	W	C index	logX	Class	Type
Abarkouh 007	24	L6	5	2.3	4.64148282	L	6
Aydar 009	13.7	L6	2	2	4.195134056	L	6
Bam 001	47.08	H5	4	2	4.805928998	H	5

Catalina 170	2790	H5	2	3.1	5.190391835	H	5
El Medano 004	134	H6	2	3.3	5.335570903	H	6
El Medano 006	51	LL6	4	2	3.95	LL	6
El Medano 008	29	L6	3	2.6	4.574192876	L	6
El Medano 009	61	L6	3	2.6	4.769634149	L	6
El Medano 011	82	H6	3	2.4	4.825038646	H	6
El Medano 012	26	H6	3	2.6	5.059199436	H	6
El Medano 014	22	H4	2	2.7	5.268902005	H	4
El Medano 015	90	H4	3	2.1	4.748531049	H	4
El Medano 016	44	L6	4	2.1	4.27853734	L	6
El Medano 017	105	L6	3	2.5	4.468507754	L	6
El Medano 021	49	H6	3	2.2	4.768016789	H	6
El Medano 022	38	H6	3	2.5	5.055422104	H	6
El Medano 023	104	L6	3	2.4	4.410846851	L	6
El Medano 026	141	L6	3	2.7	4.626135814	L	6
El Medano 028	99	L5	1	2.8	4.783198614	L	5
El Medano 030	25	H6	3	2.4	4.625479886	H	6
El Medano 032	23	H6	2	2.5	4.940267733	H	6
El Medano 033	42	H5	4	1.9	4.646392995	H	5
El Medano 035	70	H5	2	2.8	5.063807897	H	5
El Medano 036	51	H5	3	2.4	4.843265301	H	5
El Medano 037	97	L6	3	2.4	4.41846487	L	6
El Medano 043	24	H4	2	2.9	5.34248282	H	4
El Medano 044	28	L6	3	2.1	4.578600543	L	6
El Medano 046	39	H4	2	2.6	4.985216958	H	4
El Medano 047	56	H4	1	3	5.219511104	H	4
El Medano 050	52	H5	4	2.3	4.70617052	H	5
El Medano 051	28	L6	2	2.8	5.008600543	L	6
El Medano 052	66	H5	2	3	5.203040097	H	5
El Medano 053	17	H4/5	2	2.8	5.337944415	H	4.5
El Medano 054	43	H5	2	2.9	5.267337218	H	5
El Medano 059	24	H4	3	2.4	5.00148282	H	4
El Medano 060	21.6	H3	2	2.4	4.986610373	H	3
El Medano 061	55	H5	2	2.9	5.33593012	H	5
El Medano 064	17	H4	4	2.3	4.877944415	H	4
El Medano 067	16	L6	3	1.9	4.413773341	L	6
El Medano 068	54	H4	2	3.4	5.282509148	H	4
El Medano 069	65	H6	2	2.7	5.038120408	H	6
El Medano 075	128	L6	3	2.1	4.644532648	L	6
El Medano 077	70	L4	2	2.7	4.793807897	L	4
El Medano 078	40	L6	3	2.9	5.23531987	L	6
El Medano 080	24	L6	3	3.1	4.75248282	L	6
El Medano 082	20	H5	2	3	5.419036804	H	5
El Medano 084	32	H5	2.5	2.7	5.004091654	H	5
El Medano 086	806	H4	1	3.1	5.11464918	H	4
El Medano 088	9.6	L6	3	2.1	4.633122408	L	6
El Medano 089	265	L6	4	2.3	4.26	L	6

El Medano 090	16.6	L6	2	2.2	4.738081746	L	6
El Medano 093	50	H4-6	2	2.1	5.080545015	H	6
El Medano 094	35	L6	1	2.4	4.838048267	L	6
El Medano 101	15	L6	3	2.4	4.771331304	L	6
El Medano 102	63	H4/5	1	3.4	5.288631357	H	5
El Medano 105	16	H5/6	3	2.25	5.223773341	H	6
El Medano 106	79	H5/6	2	2.4	5.086119269	H	6
El Medano 108	15	H4	2	2.4	5.141331304	H	4
El Medano 109	13	H3	2	2.7	5.232626209	H	3
El Medano 116	44	H6	3	3.2	5.14853734	H	6
El Medano 117	51	L6	3	3.1	4.823265301	L	6
El Medano 120	21	H5	2	2.4	5.098462384	H	5
El Medano 121	220	H5	3	2	4.915374293	H	5
El Medano 122	53	L5/6	3	1.7	4.46925393	L	6
El Medano 123	22	H5	1	2.9	5.408902005	H	5
El Medano 124	38	H5	1	2.8	5.365422104	H	5
El Medano 125	68	L6	3	2.9	4.743212592	L	6
El Medano 129		L6	2	2.3	4.79	L	6
El Medano 130	40	L6	3	2.4	4.41531987	L	6
El Medano 131	40	H4	3	2.3	5.08531987	H	4
El Medano 132	607	H4	1	2.8	5.208131482	H	4
El Medano 133	383	LL6	1	1.4	3.999873806	LL	6
El Medano 135	44	L6	3	1.9	4.67353734	L	6
El Medano 137	30	H5	2	2.3	5.180327775	H	5
El Medano 141	301	L6	3	1.8	4.701323548	L	6
El Medano 144	47	L4	2	2.8	4.963567154	L	4
El Medano 148	286	H5	2	2.8	4.834441001	H	5
El Medano 149	98	H5	2	3.2	5.16	H	5
El Medano 152	25	H4	1	3.2	5.535479886	H	4
El Medano 158	27	H4	1	2.2	5.103588679	H	4
El Medano 160	83	H6	3	2.9	4.951491582	H	6
El Medano 161	89	H5	3	2.9	4.891622305	H	5
El Medano 162	137	L4	1	2.9	4.921400619	L	4
El Medano 164	39	H6	3	2.3	5.195216958	H	6
El Medano 166	40	L5	2	3.3	4.97531987	L	5
El Medano 167	127	H4	2	2.3	4.916112334	H	4
El Medano 180	157	H3-5	2	3.2	5.012999844	H	5
El Medano 182	71	H3	1	2.6	5.169256572	H	3
El Medano 184	460	H5	1	2.8	5.263968349	H	5
El Medano 185	28	H5	2	2.6	5.298600543	H	5
El Medano 186	80	H5	2	2.4	5.182350568	H	5
El Medano 188	18	H6	4	2.3	4.703649893	H	6
El Medano 190	610	H5	2	3.1	4.798053158	H	5
El Medano 191	122	H5	2	2.5	5.104410778	H	5
El Medano 192	15	H5/6	3	2.1	5.241331304	H	6
El Medano 213	213	L6	2	2.7	4.368615387	L	6
El Medano 311	289	LL6	2	2	4.203782219	LL	6

Foum Agoutir	22.62	L4	2	2.2	4.635244766	L	4
Gandom Beryan 014	36.31	H5	3	2.4	4.864413244	H	5
Kerman 002	19	L6	3	2.4	4.790726694	L	6
Kerman 147	23.4	H5	3	2.3	4.91305581	H	5
Kerman 200	95	L5	2	1.5	4.333930469	L	5
Kerman 250	48.14	H5	3	2.3	4.939601867	H	5
Los Vientos 443	22.66	H5	1	2.8	5.226504452	H	5
Lut 006	36.1	LL3	3	2.4	4.455717455	LL	3
Lut 012	59	L6	2	2.7	4.521160863	L	6
Lut 018	70	LL6	2	1.2	4.286807897	LL	6
NWA 10160	21	LL6	1	1.5	4.015462384	LL	6
NWA 11812	19.02	LL3	4	2	4.295281232	LL	3
NWA 12464	21.66	LL3	3	2.1	4.006444471	LL	3
NWA 12484	21	L3	1	2.5	4.742462384	L	3
NWA 12549	18.2	LL3	1	2	4.32996029	LL	3
NWA 12555	32.3	H6	4	2.2	4.78931665	H	6
NWA 12582	15.43	LL4	5	1.3	3.884255466	LL	4
NWA 12990	24.2	L6-melt breccia	1	2.9	5.109021684	L	6
NWA 13145	30	LL3	4	2.3	4.427327775	LL	3
NWA 13147	28	L4	2	2.3	4.409600543	L	4
NWA 13151	20.8	LL7	1	2	3.780493109	LL	7
NWA 13152	14.78	L3	1	2.4	4.803648507	L	3
NWA 13498	11.35	LL3	1	2.3	4.450959638	LL	3
NWA 13501	24.56	H3	3	2.5	4.901868815	H	3
NWA 13708	20.48	LL3	4	1.9	3.350028463	LL	3
NWA 14158	50.3	L6	1	2.9	4.969341266	L	6
NWA 14817	17.7	L6	0.5	2.6	5.002787376	L	6
NWA 14819	80	L6	0.5	2.8	4.811350568	L	6
NWA 14830	22.5	LL7	2	2	3.649474141	LL	7
NWA 7200	15.8	H5	1	3.2	5.540139738	H	5
NWA 7283	16.56	LL6	1	1.2	3.996109407	LL	6
NWA 8274	21.37	L6	0.5	2.8	5.010111804	L	6
NWA 8477	21.82	L5	0.5	2.7	4.895352134	L	5
NWA 8484	14.95	LL3	3	1.6	4.212758604	LL	3
Rabt Sbayta 013	20.32	LL6	1	1.8	3.742336782	LL	6
Rhourde Dabdab 001	24.8	H5	0	3.3	5.523820873	H	5
San Juan 033	332	H6	1	3.3	5.216067509	H	6
San Juan 034	187	L6	1	2.9	4.733379795	L	6
San Juan 038	146	H5	1	3.2	5.329994416	H	5
San Juan 040	32	H3-5	2	3.4	5.124091654	H	5
San Juan 044	84	H5	1	3.2	5.328014662	H	5
San Juan 057	217	L6	1	2.7	4.816730844	L	6
San Juan 059	154	L5	1	2.1	4.711080624	L	5
Seih Al Mishab 001	23	H5	3	2.55	5.058767733	H	5
Ueiiila 004	15.99	L6	0	2.65	4.977040007	L	6
Yazd 005	28.58	L5	4	2.1	4.660175916	L	5
Yazd 006	50.86	L6	3	2.1	4.607273169	L	6

Table S8 Raw data of terrestrial rocks.

rock	mass	logX	C index	Group	Class
steel	1000	6	6	steel	steel
aluminum	1000	6	6	aluminum	aluminum
andesite	1000	4.21	0	andesite	andesite
basalt	741	4.103	1.15	basalt	basalt
basalt	418	3.64	0	basalt	basalt
basalt	493	4.32	0	basalt	basalt
basalt	669	4.254	0	basalt	basalt
basalt	359	4.49	1.7	basalt	basalt
basalt	1000	3.817	0	basalt	basalt
basalt	1000	3.62	1.8	basalt	basalt
basalt	1000	4.09	2.2	basalt	basalt
basalt	297	2.41	0.9	basalt	basalt
basalt	2000	4.03	0	basalt	basalt
basalt	170.35	4.12	2	basalt	basalt
basalt	776.17	4.412	1.7	basalt	basalt
basalt	1000	3.57	1.38	basalt	basalt
basalt	1000	4.15	1.4	basalt	basalt
basalt	776	4.42	2.2	basalt	basalt
basalt	1000	3.9	0	basalt	basalt
basalt	742	4.05	1.6	basalt	basalt
basalt	440	2.83	0.5	basalt	basalt
BIF (Mauritania)	156	5.74	0	BIF (Mauritania)	BIF
BIF (Mauritania)	144	5.81	0	BIF (Mauritania)	BIF
BIF (Mauritania)	111	5.74	1.7	BIF (Mauritania)	BIF
limetsone	470	1.55	0.4	limetsone	limetsone
limetsone	386	2.29	1.1	limetsone	limetsone
calcite	115	1	0	calcite	calcite
coal	163	1	0	coal	coal
steel	11	5.63	3.8	steel	steel
steel	215	6	6	steel	steel
gabbro	1000	2.56	0.72	gabbro	gabbro
gneiss	1000	2.319	1.07	gneiss	gneiss
gneiss	1000	3.83	0	gneiss	gneiss
granite	1000	1	0	granite	granite
granite	1000	1.807	0	granite	granite
granite	512	3.59	1.3	granite	granite
granite	695	1.205	0	granite	granite
granulite	1000	2.937	0	granulite	granulite
ignimbrite	1000	2.34	1.2	ignimbrite	rhyolitic ignimbrite
ignimbrite	1000	2.1	0.6	ignimbrite	rhyolitic ignimbrite
ignimbrite	1000	2.77	1.4	ignimbrite	rhyolitic ignimbrite
ignimbrite	1000	1.9	0	ignimbrite	rhyolitic ignimbrite

marcassite	26	1	0	marcassite	marcassite
marcassite	1000	2.5	0.7	marcassite	marcassite
marcassite	1000	1.8	0	marcassite	marcassite
marcassite	200	2.2	0	marcassite	marcassite
microdiorite	211	4.21	0	microdiorite	microdiorite
pyrite	43	1	0	pyrite	pyrite
pyroxenite	880	2.566	0.72	pyroxenite	pyroxenite
quartz	1000	1	0	quartz	quartz
rhyolite	1000	2.34	1.7	rhyolite	rhyolite
serpentinite	175	4.63	0	serpentinite	serpentinite
serpentinite	909	4.22	0.24	serpentinite	serpentinite
tourmaline	83	2.51	0	tourmaline	tourmaline
