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Extreme eolian delivery of reactive iron to late Paleozoic icehouse seas

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Methods Summary

Iron Geochemistry

A standard chromium-reducible sulfur (CRS) method was used to quantify pyrite concentration (Canfield et al., 1986). Specifically, S_{pyrite} was extracted in an acidic (0.5 M HCl) $CrCl_2$ solution for 2 hours, which evolves H_2S that is re-precipitated as zinc sulfide (ZnS) in a 1.48 M NH_4OH and 0.03 M zinc acetate solution. The precipitated ZnS was quantified by titration with a 0.1 M KIO_3 solution in the presence of excess KI and starch (Canfield et al., 1986), yielding wt.% S_{pyrite} within the sample. For isotopic analysis, $\delta^{34}S_{pyrite}$ was re-precipitated as Ag_2S using the same acidic $CrCl_2$ method but with a 1.48 M NH_4OH and 30 mM $AgNO_3$ trap solution. The precipitated Ag_2S was filtered, homogenized, and weighed into tin capsules. The samples were combusted by EA coupled, through a continuous flow, to a Delta V Thermo IRMS (Isotope Ratio Mass Spectrometer). The isotope ratio ($^{34}S/^{32}S$) was calculated as $\delta^{34}S‰ = ([^{34}S/^{32}S_{sample}]/[^{34}S/^{32}S_{standard}]-1)\times1000$. The samples were corrected using a series of standards (IAEA S-1, S-2, and S-3) and Vienna Canyon Diablo Triolite (VCDT) with a long term standard error of ±0.2‰ in the Lyons' stable isotope lab at the University of California, Riverside (UCR).

For elemental analysis, ~100 mg of powder was weighed into ceramic vials and heated for ~12 hours at 450°C to volatilize all organic material. The samples were subsequently weighed after cooling to determine the loss on ignition and then transferred into trace metal clean vials and completely dissolved using a standard sequential acid protocol (nitric acid/hydrochloric acid/hydrofluoric acid) at ~150°C. Subsequent to complete dissolution, the samples were dried down and then brought up in 2% HNO_3 for analysis. All acids used in this method were trace metal grade. Concentrations were measured using an Agilent 7500ce quadrupole inductively coupled plasma mass spectrometry (ICP-MS) housed in the Lyons lab at UCR. Standard reference materials (SDO-1 shale) were digested along with the samples and analyzed with each batch of digestions and were within the accepted analytical error for all elements. Procedural blanks were below detection limits, and sample reproducibility was better than 5% for all reported elements.

We also present detailed iron speciation data, which we operationally define reactive iron (Fe_{HR}) as pyrite Fe (Fe_{py}), Fe oxides (dithionite-soluble iron; Fe_D), magnetite Fe (Fe_{mag}). We did not include Fe carbonate in our calculation for any of the samples because of the very low inorganic carbon contents of our sediments. Magnetite Fe was measured on the loess samples but the atoll samples do not include this analysis. Highly reactive iron is thus calculated as Fe_{py} + Fe_D + Fe_{mag} (if analyzed). We used pyrite sulfur concentrations from the chromium reduction procedure described above to calculate Fe_{py} assuming a stoichiometry of FeS_2. Un-pyritized reactive Fe (Fe_D and Fe_{mag}) was analyzed using a two-step sequential extraction (Poulton and Canfield, 2005, Poulton and Raiswell, 2005). Briefly, ~100 mg of sample were weighed into a 15 ml centrifuge tube and extracted as follows: (1) extraction of the sample residue for Fe_D using 50 g/L sodium dithionite buffered to a pH of 4.8 for 2 hours with constant shaking, and (3) extraction of Fe_{mag} from the remaining residue using an ammonium oxalate/oxalic acid-buffered solution at a pH of 3.2 for 6 hours. Note, the Fe_{HR} values for the Horseshoe Atoll samples only included Fe_{py} and Fe_D. All extracts were analyzed using the same ICP-MS as above.

Iron Geochemistry Methods References

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Climate, Aerosol, and Biogeochemical Modeling

Dust deposition was estimated by modeling the dust cycle using the routines of Mahowald et al. (2006) within a baseline simulation of deep glacial conditions during the Early Permian (icehouse.glaciation.huge: Heavens et al., 2012a). These routines were modified to allow emission from more vegetated surfaces and with a slightly different size distribution, following the observations of Okin (2008) and theory of Kok (2011). Dust sources were manually tuned to match reconstructed rates of dust deposition during glacials at low-latitude sites during the Late Pennsylvanian and Early Permian (Stagner, 2008; Patterson, 2011; Sur et al., 2010a), assuming that the glacial pulse of deposition in the Akiyoshi Formation (Patterson, 2011) was diluted by bioturbation under conditions of low carbonate accumulation by a factor of 15. Under this scenario, glacial deposition at the site studied by Sur et al. (2010a) is estimated to be ~ 15 g/m^2/yr, near the lower bound estimated from the sedimentological data. Late Paleozoic nitrate concentrations were estimated from LEVITUS94 dataset values at 10 m in the modern ocean (Conkright et al., 1994). Nitrate concentrations in the Late Paleozoic were estimated from the zonal mean and standard deviation of sea surface temperature in the climate simulation, which then was scaled with the zonal mean and standard deviation of nitrate concentration in the LEVITUS94 dataset. (Anomalously cool waters contain anomalous concentrations of nitrate and vice versa.) Since the bulk of the continental area today is in the Northern Hemisphere but was in the Southern Hemisphere in the Early Permian, the modern dataset was first flipped upside down (see Heavens et al., 2012b for a similar approach to parameterize aerosol forcing). (Note that flipping does not significantly impact the global estimate of carbon fixation.) Phosphate was then estimated by assuming that N:P in water is at the Redfield ratio of 16:1.

The impact of glacial dust fertilization on biological productivity was estimated by assuming that carbon fixation is based on phosphorus limitation and that diazotrophs will manufacture needed nitrogen given sufficient iron in environments similar to modern high nitrate low chlorophyll (HNLC) waters. This applies the idea that high dust delivery makes the ocean P-limited (Moore and Doney, 2007). Following Okin et al. (2011), we initially estimate carbon fixation due to dust fertilization as proportional to the deposition rate of bioavailable Fe in ice-free HNLC waters (NO3- > 4 micromolar). Dust is assumed to be 3.5% Fe by mass (Luo et al., 2008) and 70% bioavailable (soluble) for wet deposition (1.2% for dry deposition). Carbon fixation rates estimated by this method are up to < 200000 g m^-2 yr^-1, implying P-limitation is likely. We then correct this calculation for photic zone P-limitation by limiting C-fixation by the rate that can be supported by phosphate availability in a 100 m photic zone, assuming C:P in fixed organic matter is at the Redfield ratio of 106:1. Paytan and McLaughlin (2007) estimate P remineralization occurs in <1 day to two weeks; we assumed 10 days. This correction reduces the maximum rates of carbon fixation to < 11000 g m^-2 yr^-1. Assuming monthly dust deposition only over ice-free surfaces, the result is 120 Pg/yr of C fixation (or roughly 240% of the present day value of C fixation in the ocean).

Climate Modeling Methods References

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Location Data for Samples Highlighted in "Extreme Eolian Delivery of Reactive Iron to Late Paleozoic Icehouse Seas"

Table DR1. Locations and Fe Extractions from Cutler Formation

Sample ID	Latitude	Longitude	Height (m)	NaAc (wt% Fe)	Dithionite (wt% Fe)	Oxalate (wt% Fe)	Pyrite Fe (wt%)	Reactive Fe (wt% Fe)	Al (wt%)	Fe_T (wt%)	Fe_T/Al	Fe_{HR}/Fe_T
MHE6.5	37.180833	-109.831111	6.5	BDL	0.30	0.18	BDL	0.48	1.90	0.95	0.50	0.51
MHE6.65	37.180833	-109.831111	6.65	BDL	0.38	0.25	BDL	0.63	3.56	1.81	0.51	0.35
MHE7.3	37.180833	-109.831111	7.3	BDL	0.28	0.27	BDL	0.55	2.83	1.51	0.53	0.36
MHE49.6	37.180833	-109.831111	49.6	BDL	0.31	0.20	BDL	0.51	2.66	0.92	0.35	0.55
MHE71.1	37.180833	-109.831111	71.1	BDL	0.16	0.05	BDL	0.21	1.45	0.31	0.22	0.68
MHE71.5	37.180833	-109.831111	71.5	BDL	0.14	0.09	BDL	0.23	1.20	0.36	0.30	0.62
MHE71.65	37.180833	-109.831111	71.65	BDL	0.20	0.08	BDL	0.28	1.66	0.42	0.25	0.66
MHE72.5	37.180833	-109.831111	72.5	BDL	0.28	0.40	BDL	0.67	2.28	1.23	0.54	0.55
MHE91.3	37.180833	-109.831111	91.3	BDL	0.40	0.36	BDL	0.76	4.11	1.72	0.42	0.44
MHE120	37.180833	-109.831111	120	BDL	0.28	0.17	BDL	0.45	2.52	1.02	0.41	0.44
MHE131.7	37.180833	-109.831111	131.7	BDL	0.32	0.26	BDL	0.58	3.02	1.21	0.40	0.48
MHE136.3	37.180833	-109.831111	136.3	BDL	0.52	0.35	BDL	0.87	2.90	1.68	0.58	0.52
MHE151.2	37.180833	-109.831111	151.2	BDL	0.50	0.26	BDL	0.76	3.34	1.94	0.58	0.39

Table DR2. Locations and Fe Extractions from Maroon Formation

Sample ID	Latitude	Longitude	Height (m)	NaAc (wt% Fe)	Dithionite (wt% Fe)	Oxalate (wt% Fe)	Pyrite Fe (wt%)	Reactive Fe (wt% Fe)	Al (wt%)	Fe_T (wt%)	Fe_T/Al	Fe_{HR}/Fe_T
RR 4.4	39.220	-106.490	4.4	BDL	0.48	0.10	BDL	0.58	3.01	0.87	0.29	0.67
RR 5.2	39.220	-106.490	5.2	BDL	0.34	0.10	BDL	0.44	3.69	0.94	0.26	0.47
LRR 8.1	39.220	-106.490	8.1	BDL	0.62	0.14	BDL	0.76	5.04	1.67	0.33	0.45
LRR 9.1	39.220	-106.490	9.1	BDL	0.31	0.10	BDL	0.42	4.51	0.98	0.22	0.42
LRR 12.8	39.220	-106.490	12.8	BDL	0.31	0.08	BDL	0.39	3.33	0.78	0.24	0.50
LRR 15.6	39.220	-106.490	15.6	BDL	0.29	0.09	BDL	0.39	3.70	1.01	0.27	0.38
LRR 16.3	39.220	-106.490	16.3	BDL	0.36	0.09	BDL	0.45	4.09	1.10	0.27	0.41
LRR 17.0	39.220	-106.490	17	BDL	0.34	0.11	BDL	0.45	4.28	1.08	0.25	0.42
LRR 18.7	39.220	-106.490	18.7	BDL	0.33	0.13	BDL	0.46	3.68	1.01	0.27	0.46
LRR20.5	39.220	-106.490	20.5	BDL	0.28	0.09	BDL	0.37	3.61	0.96	0.27	0.38
LRR 22.9	39.220	-106.490	22.9	BDL	0.42	0.08	BDL	0.50	4.17	1.06	0.25	0.47
LRR 23.7	39.220	-106.490	23.7	BDL	0.58	0.14	BDL	0.72	5.03	1.48	0.30	0.48
LRR 25.0	39.220	-106.490	25	BDL	0.49	0.13	BDL	0.62	4.43	1.29	0.29	0.48
LRR 29.5	39.220	-106.490	29.5	BDL	0.52	0.15	BDL	0.67	3.02	1.39	0.46	0.48
LRR 30.8	39.220	-106.490	30.8	BDL	0.57	0.14	BDL	0.71	4.30	1.22	0.28	0.58
LRR 32.8	39.220	-106.490	32.8	BDL	0.62	0.15	BDL	0.77	4.66	1.50	0.32	0.51
LRR 36.6	39.220	-106.490	36.6	BDL	0.89	0.06	BDL	0.96	5.36	1.89	0.35	0.51
LRR 38.6	39.220	-106.490	38.6	BDL	1.59	0.43	BDL	2.02	8.04	4.43	0.55	0.46
LRR 49.4	39.220	-106.490	49.4	BDL	0.60	0.10	BDL	0.70	4.18	1.43	0.34	0.49
RR 55.6	39.220	-106.490	55.6	BDL	0.33	0.09	BDL	0.43	3.61	0.99	0.27	0.43
RR 61.5	39.220	-106.490	61.5	BDL	0.33	0.08	BDL	0.41	3.45	0.83	0.24	0.49
RR 66.3	39.220	-106.490	66.3	BDL	0.27	0.06	BDL	0.33	3.28	0.76	0.23	0.44
RR 69.5	39.220	-106.490	69.5	BDL	0.35	0.07	BDL	0.42	3.64	0.84	0.23	0.49
RR 90.5	39.220	-106.490	90.5	BDL	0.40	0.09	BDL	0.50	4.00	0.99	0.25	0.50
RR 92.8	39.220	-106.490	92.8	BDL	0.46	0.10	BDL	0.56	3.53	0.95	0.27	0.59
M 204.20	39.220	-106.490	204.2	BDL	0.36	0.27	BDL	0.63	2.78	0.75	0.27	0.84
M 205.00	39.220	-106.490	205	BDL	0.24	0.14	BDL	0.38	2.71	0.65	0.24	0.58

M 205.20	39.220	-106.490	205.2	BDL	0.23	0.14	BDL	0.38	2.55	0.59	0.23	0.64
M 205.6	39.220	-106.490	205.6	BDL	0.33	0.08	BDL	0.41	3.40	0.81	0.24	0.51
M 205.60	39.220	-106.490	205.6	BDL	0.21	0.13	BDL	0.34	2.88	0.76	0.26	0.45
M 206.7	39.220	-106.490	206.7	BDL	1.12	0.19	BDL	1.31	5.44	1.90	0.35	0.69
M 206.9	39.220	-106.490	206.9	BDL	0.61	0.12	BDL	0.73	4.55	1.29	0.28	0.57
M 207.7	39.220	-106.490	207.7	BDL	0.49	0.25	BDL	0.74	3.62	0.93	0.26	0.80
M 209.80	39.220	-106.490	209.8	BDL	0.30	0.18	BDL	0.48	3.17	1.06	0.34	0.45
M 210.10	39.220	-106.490	210.1	BDL	0.33	0.18	BDL	0.51	3.07	1.00	0.32	0.51
M 210.60	39.220	-106.490	210.6	BDL	0.29	0.17	BDL	0.46	2.96	0.84	0.28	0.54
M 212.10	39.220	-106.490	212.1	BDL	0.36	0.21	BDL	0.57	3.26	1.19	0.37	0.48
M 212.7	39.220	-106.490	212.7	BDL	0.62	0.09	BDL	0.71	4.09	1.12	0.27	0.63
M 212.70	39.220	-106.490	212.7	BDL	0.41	0.25	BDL	0.66	2.96	1.01	0.34	0.66
M 213.80	39.220	-106.490	213.8	BDL	0.27	0.13	BDL	0.39	2.72	0.82	0.30	0.48
M 214.80	39.220	-106.490	214.8	BDL	0.28	0.18	BDL	0.46	2.21	0.63	0.29	0.72

Table DR3. Locations and Fe Extractions from Modern dust samples

Sample ID	Latitude	Longitude	Height (m)	NaAc (wt% Fe)	Dithionite (wt% Fe)	Oxalate (wt% Fe)	Pyrite Fe (wt%)	Reactive Fe (wt% Fe)	Al (wt%)	Fe_T (wt%)	Fe_T/ Al	Fe_{HR}/ Fe_T
Saharan	21.6981	-71.5061		0.018	1.62	2.07	BDL	3.71	10.34	7.71	0.75	0.48
Alaskan	69.5833	-156.583		0.230	0.43	0.18	BDL	0.83	2.84	2.03	0.72	0.41
NZ Tekapo	-44.0157	170.404		BDL	0.42	0.08	BDL	0.50	6.20	2.48	0.40	0.20
NZ Irishman	-44.198	170.2809		BDL	0.48	0.06	BDL	0.54	6.21	2.56	0.41	0.21
NZ Fairlie	-44.053	170.8949		BDL	0.47	0.23	BDL	0.70	6.83	3.13	0.46	0.23
China	40.0922	115.2955	0.5	BDL	0.32	0.26	BDL	0.58	5.92	3.07	0.52	0.19
China	40.0922	115.2955	1	BDL	0.60	0.14	BDL	0.74	8.29	3.44	0.42	0.21
China	40.0922	115.2955	6	BDL	0.45	0.16	BDL	0.61	7.25	2.84	0.39	0.21
China	40.0922	115.2955	14.5	BDL	0.54	0.15	BDL	0.69	7.18	2.89	0.40	0.24
China	40.0922	115.2955	20.5	BDL	0.38	0.15	BDL	0.54	6.84	2.55	0.37	0.21
China	40.0922	115.2955	22.2	BDL	0.43	0.16	BDL	0.60	7.22	2.61	0.36	0.23
Elba	41.2934	-98.5156	1.1	BDL	0.13	0.15	BDL	0.28	4.04	1.78	0.44	0.16
Elba	41.2934	-98.5156	1.3	BDL	0.12	0.16	BDL	0.28	4.23	1.84	0.44	0.15
Elba	41.2934	-98.5156	1.6	BDL	0.11	0.13	BDL	0.24	4.00	1.73	0.43	0.14
Elba	41.2934	-98.5156	1.9	BDL	0.12	0.13	BDL	0.24	4.12	1.80	0.44	0.14
Elba	41.2934	-98.5156	2.2	BDL	0.17	0.20	BDL	0.37	4.28	2.00	0.47	0.18
Elba	41.2934	-98.5156	3.3	BDL	0.16	0.19	BDL	0.35	4.12	1.90	0.46	0.18
Elba	41.2934	-98.5156	6.7	BDL	0.13	0.16	BDL	0.28	3.84	1.73	0.45	0.16
Elba	41.2934	-98.5156	7.9	BDL	0.20	0.24	BDL	0.44	4.04	2.04	0.51	0.21
Elba	41.2934	-98.5156	9.1	BDL	0.20	0.21	BDL	0.40	4.42	2.34	0.53	0.17
Elba	41.2934	-98.5156	10.30	BDL	0.18	0.22	BDL	0.40	4.07	2.23	0.55	0.18
Elba	41.2934	-98.5156	10.90	BDL	0.17	0.19	BDL	0.36	4.04	2.23	0.55	0.16
Elba	41.2934	-98.5156	11.20	BDL	0.21	0.25	BDL	0.45	4.37	2.25	0.52	0.20
Elba	41.2934	-98.5156	11.50	BDL	0.20	0.21	BDL	0.41	4.35	2.42	0.56	0.17
Elba	41.2934	-98.5156	11.80	BDL	0.16	0.18	BDL	0.35	4.24	2.30	0.54	0.15
Elba	41.2934	-98.5156	12.10	BDL	0.18	0.19	BDL	0.36	4.08	2.15	0.53	0.17
Elba	41.2934	-98.5156	12.40	BDL	0.17	0.20	BDL	0.37	4.14	2.03	0.49	0.18
Elba	41.2934	-98.5156	13.60	BDL	0.23	0.25	BDL	0.48	4.00	1.97	0.49	0.24
Elba	41.2934	-98.5156	13.80	BDL	0.23	0.23	BDL	0.46	4.25	2.09	0.49	0.22

Elba	41.2934	-98.5156	15.80	BDL	0.10	0.12	BDL	0.22	4.17	1.92	0.46	0.12
Elba	41.2934	-98.5156	16.10	BDL	0.17	0.20	BDL	0.37	4.01	1.86	0.46	0.20
Elba	41.2934	-98.5156	16.40	BDL	0.15	0.18	BDL	0.32	4.29	1.92	0.45	0.17
Elba	41.2934	-98.5156	16.60	BDL	0.20	0.21	BDL	0.41	4.09	2.04	0.50	0.20
Elba	41.2934	-98.5156	16.90	BDL	0.20	0.22	BDL	0.42	4.09	2.01	0.49	0.21
Elba	41.2934	-98.5156	19.10	BDL	0.21	0.19	BDL	0.40	3.80	1.70	0.45	0.23

Table DR4. Locations and Fe Extractions from Horseshoe Atoll (Reinecke Field, Well # 266

Sample ID	Latitude	Longitude	Depth (m)	NaAc (wt% Fe)	Dithionite (wt% Fe)	Oxalate (wt% Fe)	Pyrite Fe (wt%)	Reactive Fe (wt% Fe)	Al (wt%)	Fe_T (wt%)	Fe_T/ Al	Fe_{HR}/ Fe_T
S- 2	32.5634	-101.253	2104.36	N/A	0.12	N/A	1.67	1.78	7.69	2.55	0.33	0.70
S- 4	32.5634	-101.253	2104.41	N/A	0.13	N/A	1.68	1.81	8.04	2.56	0.32	0.71
S- 8	32.5634	-101.253	2104.50	N/A	0.13	N/A	2.46	2.58	7.98	3.31	0.41	0.78
S- 12	32.5634	-101.253	2104.60	N/A	0.14	N/A	1.76	1.89	8.00	2.88	0.36	0.66
S-16	32.5634	-101.253	2104.69	N/A	0.01	N/A	2.17	2.19	8.04	3.2	0.40	0.68

Table DR5. Locations and Fe Extractions from Permian loess samples

Sample ID	Latitude	Longitude	Height (m)	NaAc (wt% Fe)	Dithionite (wt% Fe)	Oxalate (wt% Fe)	Pyrite Fe (wt%)	Reactive Fe (wt% Fe)	Al (wt%)	Fe_T (wt%)	Fe_T/Al	Fe_{HR}/Fe_T
BLAINE	35.92	-98.39	420	BDL	0.825	0.473	BDL	1.30	6.46	4.59	0.71	0.28
CLOUD	35.52	-99.02	472	BDL	0.342	0.246	BDL	0.59	4.11	1.55	0.38	0.38
ELK	35.48	-99.56	636	BDL	1.121	0.638	BDL	1.76	4.28	2.91	0.68	0.61
*GH202.1	36.01	-103.46	1534	0.129	0.202	0.333	BDL	0.66	2.61	1.83	0.70	0.36
*GW-11	35.98	-103.48	1531	0.038	0.356	0.250	BDL	0.64	3.48	1.41	0.40	0.46
*GW-17	35.98	-103.48	1531	BDL	0.420	0.519	BDL	0.94	5.38	2.32	0.43	0.41
*LIBBY-L	35.95	-103.61	1440	0.116	0.603	0.411	BDL	1.13	4.06	2.26	0.56	0.50
*P107.5	35.86	-103.31	1460	BDL	0.289	0.326	BDL	0.61	3.15	1.15	0.37	0.53
*REEDING	35.89	-103.56	1416	BDL	0.676	0.404	BDL	1.08	3.72	1.85	0.50	0.58
*SB-1	35.86	-103.31	1460	BDL	0.276	0.330	BDL	0.61	3.30	1.15	0.35	0.53
*SE-1	35.86	-103.31	1460	0.006	0.517	0.377	BDL	0.90	3.14	0.98	0.31	0.92

Note: * Indicates this is core of Abo/Tubb from the Bravo Dome CO2 field (NM)

Table DR6. Dust Extractions from Horseshoe Atoll (Reinecke Field, Well # 266; Elevation KB: 716.8896 m)

Sample #	Depth in meters (su	Latitude	Longitude	TOC (wt%)	
1	2106.05	32.56335	-101.25288		
2	2105.92	32.56335	-101.25288		
3	2105.86	32.56335	-101.25288		
4	2105.82	32.56335	-101.25288		
5	2105.77	32.56335	-101.25288		
6	2105.73	32.56335	-101.25288		
7	2105.68	32.56335	-101.25288		
8	2105.62	32.56335	-101.25288		
9	2105.41	32.56335	-101.25288		
10	2105.31	32.56335	-101.25288		
11	2105.28	32.56335	-101.25288		
12	2105.22	32.56335	-101.25288		
13	2105.18	32.56335	-101.25288		
14	2105.13	32.56335	-101.25288		
15	2105.07	32.56335	-101.25288		
16	2105.01	32.56335	-101.25288		
17	2104.98	32.56335	-101.25288		
18	2104.93	32.56335	-101.25288		
19	2104.88	32.56335	-101.25288		
20	2104.83	32.56335	-101.25288		
21	2104.77	32.56335	-101.25288		
22	2104.74	32.56335	-101.25288		
S-16	2104.69	32.56335	-101.25288	0.125	S-16
S-15	2104.67	32.56335	-101.25288		
S-14	2104.64	32.56335	-101.25288		
S-13	2104.62	32.56335	-101.25288		
S-12	2104.60	32.56335	-101.25288	0.18	S-12
S-11	2104.57	32.56335	-101.25288		
S-10	2104.55	32.56335	-101.25288		
S-9	2104.53	32.56335	-101.25288		
S-8	2104.50	32.56335	-101.25288	0.25	S-8
S-7	2104.48	32.56335	-101.25288		
S-6	2104.46	32.56335	-101.25288		
S-5	2104.43	32.56335	-101.25288		
S-4	2104.41	32.56335	-101.25288	0.15	S-4
S-3	2104.39	32.56335	-101.25288		
S-2	2104.36	32.56335	-101.25288	0.205	S-2
S-1	2104.34	32.56335	-101.25288		
39	2104.29	32.56335	-101.25288		
40	2104.25	32.56335	-101.25288		
41	2104.20	32.56335	-101.25288		

42	2104.16	32.56335	-101.25288
43	2104.10	32.56335	-101.25288
44	2104.06	32.56335	-101.25288
45	2103.99	32.56335	-101.25288
46	2103.94	32.56335	-101.25288
47	2103.87	32.56335	-101.25288
48	2103.82	32.56335	-101.25288
49	2103.76	32.56335	-101.25288
50	2103.73	32.56335	-101.25288
51	2103.68	32.56335	-101.25288
52	2103.64	32.56335	-101.25288
53	2103.58	32.56335	-101.25288
54	2103.55	32.56335	-101.25288
55	2103.46	32.56335	-101.25288
56	2103.39	32.56335	-101.25288
57	2103.35	32.56335	-101.25288
58	2103.30	32.56335	-101.25288
59	2103.24	32.56335	-101.25288
60	2103.20	32.56335	-101.25288
61	2103.12	32.56335	-101.25288
62	2103.06	32.56335	-101.25288
63	2103.00	32.56335	-101.25288
64	2102.94	32.56335	-101.25288
65	2102.91	32.56335	-101.25288
66	2102.85	32.56335	-101.25288
67	2102.66	32.56335	-101.25288
68	2102.54	32.56335	-101.25288
69	2102.46	32.56335	-101.25288
70	2102.36	32.56335	-101.25288
71	2102.27	32.56335	-101.25288
72	2102.13	32.56335	-101.25288
73	2102.02	32.56335	-101.25288
74	2101.92	32.56335	-101.25288
75	2101.81	32.56335	-101.25288
76	2101.72	32.56335	-101.25288
77	2101.63	32.56335	-101.25288
78	2101.50	32.56335	-101.25288
79	2101.41	32.56335	-101.25288
80	2101.32	32.56335	-101.25288
81	2101.20	32.56335	-101.25288
82	2101.11	32.56335	-101.25288
83	2100.96	32.56335	-101.25288
84	2100.86	32.56335	-101.25288
85	2100.76	32.56335	-101.25288

86	2100.61	32.56335	-101.25288
87	2100.53	32.56335	-101.25288
88	2100.41	32.56335	-101.25288
89	2100.29	32.56335	-101.25288
90	2100.16	32.56335	-101.25288
91	2100.07	32.56335	-101.25288
92	2099.92	32.56335	-101.25288
93	2099.80	32.56335	-101.25288
94	2099.68	32.56335	-101.25288
95	2099.58	32.56335	-101.25288
96	2099.49	32.56335	-101.25288
97	2099.37	32.56335	-101.25288
98	2099.25	32.56335	-101.25288
99	2099.07	32.56335	-101.25288
100	2098.97	32.56335	-101.25288
101	2098.88	32.56335	-101.25288
102	2098.75	32.56335	-101.25288
103	2098.64	32.56335	-101.25288
104	2098.55	32.56335	-101.25288
105	2098.50	32.56335	-101.25288
106	2098.33	32.56335	-101.25288
107	2098.18	32.56335	-101.25288
108	2098.09	32.56335	-101.25288
109	2098.00	32.56335	-101.25288
110	2097.85	32.56335	-101.25288
111	2097.76	32.56335	-101.25288
112	2097.66	32.56335	-101.25288
113	2097.54	32.56335	-101.25288
114	2097.45	32.56335	-101.25288
115	2097.36	32.56335	-101.25288
116	2097.25	32.56335	-101.25288
117	2097.15	32.56335	-101.25288
118	2097.05	32.56335	-101.25288
119	2096.93	32.56335	-101.25288
120	2096.84	32.56335	-101.25288
121	2096.72	32.56335	-101.25288
122	2096.63	32.56335	-101.25288
123	2096.52	32.56335	-101.25288
124	2096.38	32.56335	-101.25288
125	2096.29	32.56335	-101.25288
126	2096.20	32.56335	-101.25288
127	2096.08	32.56335	-101.25288
128	2095.99	32.56335	-101.25288
129	2095.87	32.56335	-101.25288

130	2095.73	32.56335	-101.25288
131	2095.62	32.56335	-101.25288
132	2095.53	32.56335	-101.25288
133	2095.42	32.56335	-101.25288
134	2095.32	32.56335	-101.25288
135	2095.23	32.56335	-101.25288
136	2095.10	32.56335	-101.25288
137	2095.00	32.56335	-101.25288
138	2094.89	32.56335	-101.25288
139	2094.80	32.56335	-101.25288
140	2094.68	32.56335	-101.25288
141	2094.56	32.56335	-101.25288
142	2094.43	32.56335	-101.25288
143	2094.34	32.56335	-101.25288
144	2094.19	32.56335	-101.25288
145	2094.10	32.56335	-101.25288
146	2093.98	32.56335	-101.25288
147	2093.88	32.56335	-101.25288
148	2093.76	32.56335	-101.25288
149	2093.64	32.56335	-101.25288
150	2093.47	32.56335	-101.25288
151	2093.40	32.56335	-101.25288
152	2093.27	32.56335	-101.25288
153	2093.18	32.56335	-101.25288
154	2092.97	32.56335	-101.25288
155	2092.88	32.56335	-101.25288
156	2092.76	32.56335	-101.25288
157	2092.67	32.56335	-101.25288
158	2092.57	32.56335	-101.25288
159	2092.48	32.56335	-101.25288
160	2092.39	32.56335	-101.25288
161	2092.30	32.56335	-101.25288
162	2092.12	32.56335	-101.25288
163	2092.03	32.56335	-101.25288
164	2091.93	32.56335	-101.25288
165	2091.84	32.56335	-101.25288
166	2091.74	32.56335	-101.25288
167	2091.63	32.56335	-101.25288
168	2091.54	32.56335	-101.25288
169	2091.45	32.56335	-101.25288
170	2091.34	32.56335	-101.25288
171	2091.23	32.56335	-101.25288
172	2091.14	32.56335	-101.25288
173	2091.03	32.56335	-101.25288

174	2090.93	32.56335	-101.25288
175	2090.84	32.56335	-101.25288
176	2090.71	32.56335	-101.25288
177	2090.62	32.56335	-101.25288
178	2090.53	32.56335	-101.25288
179	2090.41	32.56335	-101.25288
180	2090.32	32.56335	-101.25288
181	2090.23	32.56335	-101.25288
182	2090.14	32.56335	-101.25288
183	2089.98	32.56335	-101.25288
184	2089.88	32.56335	-101.25288
185	2089.77	32.56335	-101.25288
186	2089.66	32.56335	-101.25288
187	2089.56	32.56335	-101.25288
188	2089.45	32.56335	-101.25288
189	2089.31	32.56335	-101.25288
190	2089.22	32.56335	-101.25288
191	2089.13	32.56335	-101.25288
192	2089.04	32.56335	-101.25288
193	2088.95	32.56335	-101.25288
194	2088.86	32.56335	-101.25288
195	2088.73	32.56335	-101.25288
196	2088.64	32.56335	-101.25288
197	2088.55	32.56335	-101.25288
198	2088.40	32.56335	-101.25288
199	2088.31	32.56335	-101.25288
200	2088.22	32.56335	-101.25288
201	2088.09	32.56335	-101.25288
202	2088.00	32.56335	-101.25288
203	2087.91	32.56335	-101.25288
204	2087.82	32.56335	-101.25288
205	2087.73	32.56335	-101.25288
206	2087.64	32.56335	-101.25288
207	2087.51	32.56335	-101.25288
208	2087.42	32.56335	-101.25288
209	2087.33	32.56335	-101.25288
210	2087.21	32.56335	-101.25288
211	2087.12	32.56335	-101.25288
212	2087.03	32.56335	-101.25288
213	2086.90	32.56335	-101.25288
214	2086.81	32.56335	-101.25288
215	2086.69	32.56335	-101.25288
216	2086.57	32.56335	-101.25288
217	2086.48	32.56335	-101.25288

218	2086.39	32.56335	-101.25288
219	2086.26	32.56335	-101.25288
220	2086.17	32.56335	-101.25288
221	2086.08	32.56335	-101.25288
222	2085.99	32.56335	-101.25288
223	2085.90	32.56335	-101.25288
224	2085.81	32.56335	-101.25288
225	2085.65	32.56335	-101.25288
226	2085.56	32.56335	-101.25288
227	2085.47	32.56335	-101.25288
228	2085.35	32.56335	-101.25288
229	2085.26	32.56335	-101.25288
230	2085.17	32.56335	-101.25288
231	2085.08	32.56335	-101.25288
232	2084.95	32.56335	-101.25288
233	2084.89	32.56335	-101.25288
234	2084.77	32.56335	-101.25288
235	2084.68	32.56335	-101.25288
236	2084.56	32.56335	-101.25288
237	2084.44	32.56335	-101.25288
238	2084.34	32.56335	-101.25288
239	2084.25	32.56335	-101.25288
240	2084.16	32.56335	-101.25288
241	2084.07	32.56335	-101.25288
242	2083.98	32.56335	-101.25288
243	2083.86	32.56335	-101.25288
244	2083.77	32.56335	-101.25288
245	2083.67	32.56335	-101.25288
246	2083.52	32.56335	-101.25288
247	2083.43	32.56335	-101.25288
248	2083.34	32.56335	-101.25288
249	2083.22	32.56335	-101.25288
250	2083.13	32.56335	-101.25288
251	2083.00	32.56335	-101.25288
252	2082.91	32.56335	-101.25288
253	2082.82	32.56335	-101.25288
254	2082.70	32.56335	-101.25288
255	2082.61	32.56335	-101.25288
256	2082.52	32.56335	-101.25288
257	2082.39	32.56335	-101.25288
258	2082.30	32.56335	-101.25288
259	2082.21	32.56335	-101.25288
260	2082.03	32.56335	-101.25288
261	2081.94	32.56335	-101.25288

262	2081.84	32.56335	-101.25288
263	2081.75	32.56335	-101.25288
264	2081.71	32.56335	-101.25288
265	2081.66	32.56335	-101.25288
266	2081.62	32.56335	-101.25288
267	2081.57	32.56335	-101.25288
268	2081.52	32.56335	-101.25288
269	2081.43	32.56335	-101.25288
270	2081.39	32.56335	-101.25288
271	2081.33	32.56335	-101.25288
272	2081.28	32.56335	-101.25288
273	2081.24	32.56335	-101.25288
274	2081.19	32.56335	-101.25288
275	2081.11	32.56335	-101.25288
276	2081.05	32.56335	-101.25288
277	2081.02	32.56335	-101.25288
278	2080.96	32.56335	-101.25288
279	2080.93	32.56335	-101.25288
280	2080.87	32.56335	-101.25288
281	2080.81	32.56335	-101.25288
282	2080.76	32.56335	-101.25288
283	2080.72	32.56335	-101.25288
284	2080.67	32.56335	-101.25288
285	2080.63	32.56335	-101.25288
286	2080.56	32.56335	-101.25288
287	2080.50	32.56335	-101.25288
288	2080.46	32.56335	-101.25288
289	2080.41	32.56335	-101.25288
290	2080.35	32.56335	-101.25288
291	2080.32	32.56335	-101.25288
292	2080.21	32.56335	-101.25288
293	2080.17	32.56335	-101.25288
294	2080.12	32.56335	-101.25288
295	2080.08	32.56335	-101.25288
296	2080.03	32.56335	-101.25288
297	2079.99	32.56335	-101.25288
298	2079.92	32.56335	-101.25288
299	2079.86	32.56335	-101.25288
300	2079.82	32.56335	-101.25288
301	2079.77	32.56335	-101.25288
302	2079.71	32.56335	-101.25288
303	2079.67	32.56335	-101.25288
304	2079.59	32.56335	-101.25288
305	2079.54	32.56335	-101.25288

306	2079.50	32.56335	-101.25288
307	2079.45	32.56335	-101.25288
308	2079.41	32.56335	-101.25288
309	2079.32	32.56335	-101.25288
310	2079.25	32.56335	-101.25288
311	2079.21	32.56335	-101.25288
312	2079.16	32.56335	-101.25288
313	2079.10	32.56335	-101.25288
314	2079.04	32.56335	-101.25288
315	2079.01	32.56335	-101.25288