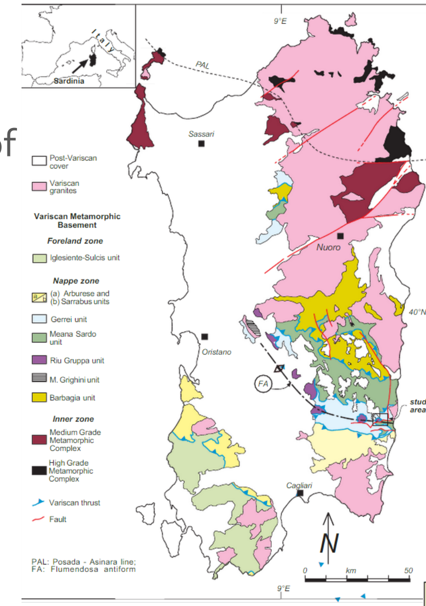
Lead Contamination of the Surface Water at the Old Baccu Locci Mine Area in Sardinia, Italy

Tristan Brougham

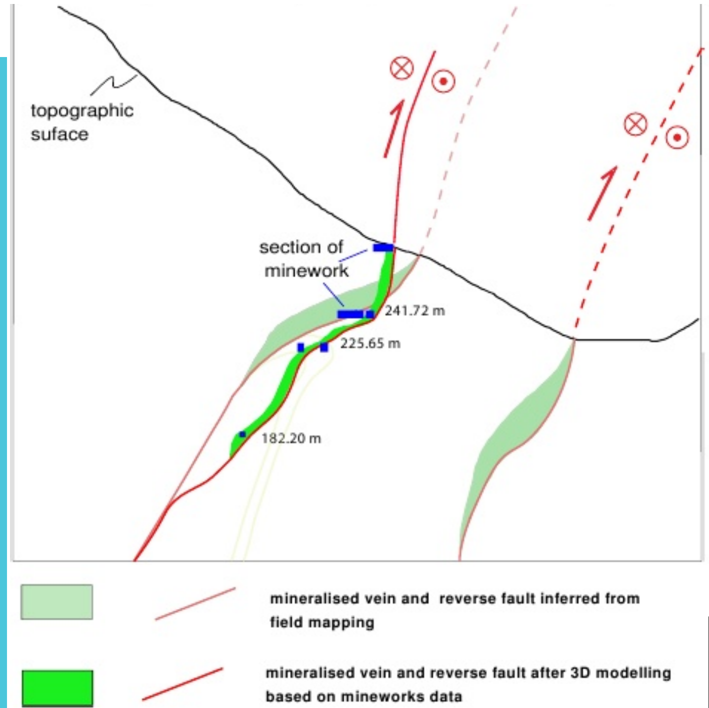
Geol 428 NDSU Fall 2014

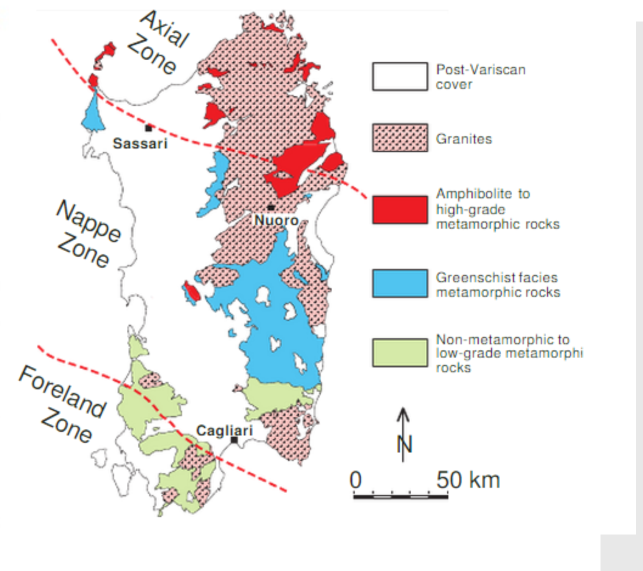
Background

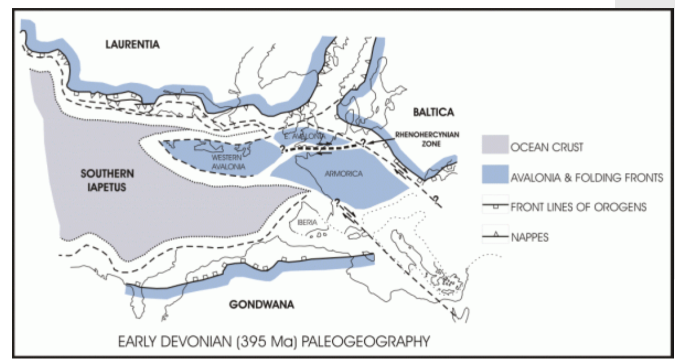
- Located in the South East of Sardinia, near Villaputzu, Cagliari Province
- Mining shut down in mid to late 20th centaury
- Baccu Locci is an arsenic, lead and zinc mine
- Severe As contamination also
- Pillar and stall mining technique
- World Health Organization limits 10 micrograms/L
- Italian Limits 50 micrograms/L…. 5x that of the WHO!



Background-Geology







Repercussions of Lead contamination

Blood Lead Level	Health Effects
Blood lead levels below 5µg/dL	**Children:** Decreased academic achievement, decreased IQ, and decreases in specific cognitive measures, increased incidence of attention-related behaviors and problem behaviors **Adults:** Decreased kidney function, maternal blood lead associated with reduced fetal growth
Blood lead levels below 10µg/dL	**Children:** Delayed puberty, reduced postnatal growth, decreased IQ and decreased hearing **Adults:** Increased blood pressure, increased risk of hypertension, and increased incidence of essential tremor

Previous Study

- Franco Frau's Paper 'Environmental geochemistry and mineralogy of lead at the old mine area of Baccu Locci (south-east Sardinia, Italy)'
- Focused on the precipitation or dissolution of Pb bearing Jarosite, which I didn't find in my modeling.
- His results of speciation-solubility calculations with PHREEQC and field evidence suggest that Pb could precipitate as As-containing plumbojarosite
- He admits to possibly poor and unreliable results of his Pb and Pb-As jasorsite

My Study

- Selection of 2 important sample sites for comparison.
- Further Investigation as to the affect of pH on the saturation of Pb bearing minerals

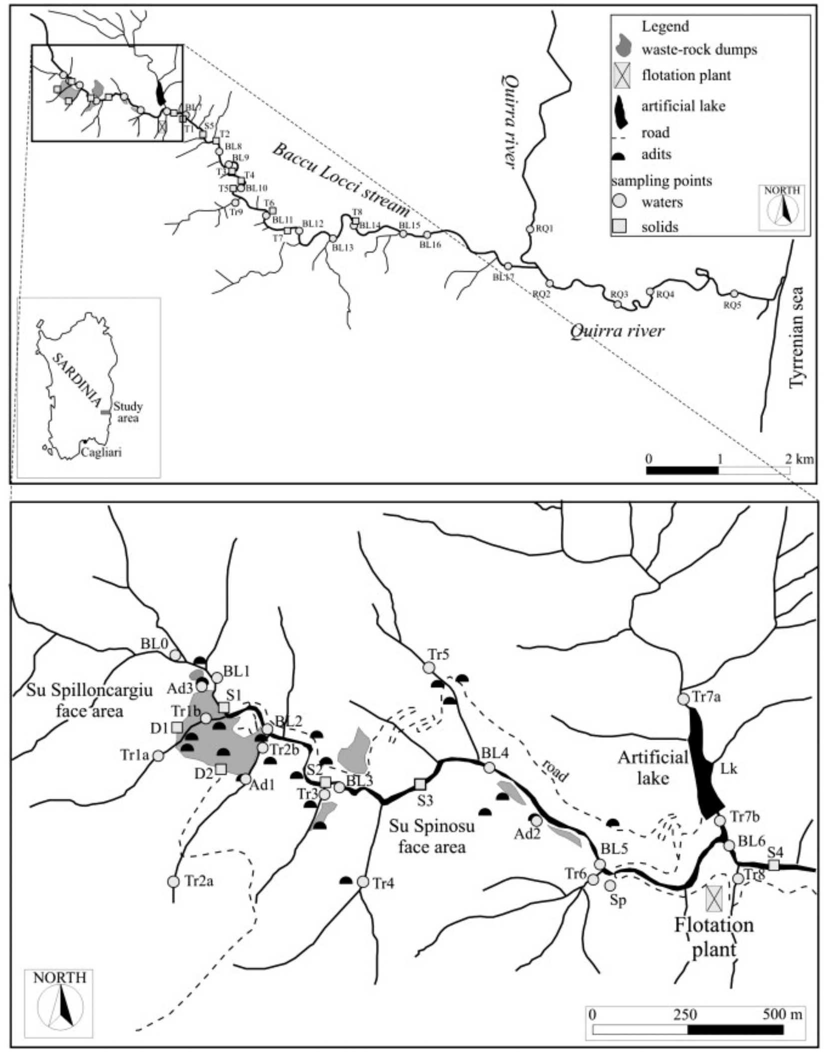


Table of results from sampling

Sample	T	pH	Eh	TDS	Ca	Mg	Na	K	Alk	Cl	SO_4	SiO_2	Al	Mn	Fe	Cu	Zn	As	Cd	Pb
	°C		V	g/L	mg/L								µg/L							
BL0	11	7.7	0.48	0.21	35	12	22	<1.4	110	50	33	5.1	43	1.8	24	6	61	15	1.3	0.97
BL1	11	7.8	0.50	0.22	38	12	22	<1.4	110	48	42	5.6	53	11	21	26	360	110	5.5	3.8
BL2	11	7.7	0.50	0.26	43	13	21	<1.4	91	47	79	6.2	140	74	19	83	5900	90	91	23
BL3	11	7.5	0.54	0.26	42	13	20	<1.4	74	44	92	6.7	25	5.4	<6.2	29	4200	200	85	12
BL4	12	7.6	0.50	0.19	29	9	18	<1.4	64	37	53	5.8	130	13	64	40	1700	160	40	29
BL5	12	7.5	0.48	0.19	30	10	19	<1.4	61	37	58	6.0	140	21	69	37	1400	150	32	26
BL6	11	7.9	0.48	0.23	37	12	20	<1.4	62	44	77	6.4	38	5.4	20	14	650	270	15	7.4
BL7	12	7.9	0.45	0.22	36	11	19	1.7	57	39	74	6.3	120	9.8	66	26	470	300	10	16
BL8	12	7.9	0.47	0.23	39	11	19	1.8	55	40	83	6.2	69	2.9	48	15	180	480	4.4	9.9
BL9	12	7.9	0.47	0.26	44	12	20	1.8	64	41	97	6.7	35	1.8	22	9.5	170	560	4.3	4.8
BL10	12	7.9	0.48	0.28	51	13	21	2.0	66	43	110	6.5	11	0.8	10	8.1	140	720	4.2	2.1
BL11	12	8.0	0.47	0.22	35	11	21	2.0	53	45	72	7.0	30	1.3	28	5.9	71	370	2.2	1.2
BL12	12	7.8	0.47	0.24	39	12	22	2.1	62	46	78	7.3	3.1	0.53	<6.2	4.2	68	480	2.3	0.49
BL13	11	7.7	0.48	0.22	34	11	23	1.7	59	49	66	6.9	5.1	0.32	<6.6	5.5	56	490	1.9	0.64
BL14	11	7.8	0.48	0.27	39	14	28	2.0	71	58	79	7.6	4.2	0.81	<6.6	5.6	50	450	1.8	0.47
BL15	11	7.6	0.48	0.25	37	12	25	2.0	66	54	74	8.8	5	0.38	<6.6	4.9	33	440	1.2	0.57
BL16	14	7.7	0.45	0.27	40	14	26	1.8	71	54	87	11	4.1	0.58	<6.2	3.2	30	370	1.1	0.55
BL17	15	7.0	0.47	0.42	70	19	34	2.5	110	59	160	10	8.9	114	21	8	188	670	2.71	1.82
RQ1	11	7.5	0.48	0.29	47	18	25	1.3	160	48	54	8.1	4.6	78	110	1.6	14	2	0.11	1.2
RQ2	12	7.4	0.48	0.28	47	18	28	1.7	170	53	39	9.1	3.1	57	62	2.1	22	22	0.15	1.6
RQ3	12	7.3	0.49	0.30	51	20	25	1.4	180	44	54	9.3	7.8	120	142	1.7	40	31	0.62	1.6
RQ4	13	7.6	0.48	0.83	64	37	170	7.1	220	360	68	9.7	3.2	71	168	1.3	9.0	25	0.13	0.77
RQ5	12	7.9	0.47	1.70	69	68	420	16	200	870	140	8.2	4.5	28	53	2.9	9.0	24	0.13	0.77
Tr1a	11	8.1	0.48	0.27	51	14	23	<1.4	150	54	40	5.2	40	15	17	19	760	24	11	4.8
Tr1b	11	7.1	0.56	0.48	60	20	21	<1.4	70	46	230	8.6	1100	1200	41	880	45000	30	670	42
Tr2a	11	7.9	0.48	0.25	49	13	22	<1.4	160	49	34	5.5	33	8.4	9.7	57	370	33	17	91
Tr2b	11	7.3	0.54	0.41	50	16	19	1.6	89	41	180	8.3	650	750	14	1000	47000	11	940	250
Tr3	11	7.9	0.53	0.20	27	11	21	<1.4	45	44	68	8.0	670	160	8.0	43	320	130	7.3	3.7
Tr4	11	7.9	0.46	0.19	29	10	23	<1.4	74	49	38	5.1	35	0.9	20	10	55	4.0	1.4	4.8
Tr6	12	8.1	0.48	0.25	36	14	29	1.6	120	57	44	7.7	15	2.9	20	2.1	11	71	0.14	1.4
Tr7a	11	8.0	0.49	0.29	59	14	22	<1.4	170	51	53	6.3	3.0	0.81	<6.2	1.9	21	250	0.23	0.31
Tr7b	11	8.1	0.47	0.40	78	21	33	2.3	240	72	70	7.2	1.0	3.8	8.9	1.4	17	500	0.37	0.64
Tr9	12	7.5	0.47	0.16	19	8.1	21	1.9	31	44	38	7.2	53	1.2	33	4.8	30	11	0.55	1.0
Lk	11	8.0	0.47	0.32	59	18	28	2.2	190	61	54	3.2	4.5	5.6	17	1.7	20	220	0.42	0.58
Ad1	11	4.4	0.69	1.99	83	47	13	4.6	–	28	1200	23	3100	5900	396	6900	510000	10	1100	1600
Ad2	11	4.8	0.53	1.03	160	52	28	2.7	–	49	670	22	6900	3300	4509	140	9700	120	61	240
Ad3	11	7.4	0.52	0.39	56	25	20	1.7	51	36	210	16	260	410	19	27	3300	120	22	2.0

Alkalinity (Alk) is reported as HCO_3. BL = Baccu Locci stream waters; RQ = Rio Quirra river; Tr = tributaries; Ad = adit waters.

PHREEQC MODELLING- BL6 sample site

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-----------------------------------
Reading input data for simulation 1.
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        TITLE BL6 Initial Results
        SOLUTION 1
                pH 7.9
                temp 11
                pe 79.87
                units mg/L
                Alkalinity 62
                Al 0.038
                Cd 0.015
                Ca 37
                Cl 44
                Cu 0.014
                Fe 0.02
                Pb 0.0074
                Mg 12
                Mn 0.0054
                K 1.4
                Si 6.4 as SiO2
                Na 20
                S 77 as SO4-2
                Zn 0.65
        EQUILIBRIUM_PHASES 1
                O2(g) -0.678
                CO2(g) -3.46
        END
```

```
-----------------------------Solution composition------------------------------

        Elements           Molality       Moles

        Al                1.330e-06   1.330e-06
        Alkalinity        1.183e-03   1.183e-03
        Ca                8.810e-04   8.810e-04
        Cd                1.270e-07   1.270e-07
        Cl                1.262e-03   1.262e-03
        Cu                2.076e-07   2.076e-07
        Fe                3.441e-07   3.441e-07
        K                 3.592e-05   3.592e-05
        Mg                4.710e-04   4.710e-04
        Mn                9.670e-08   9.670e-08
        Na                8.728e-04   8.728e-04
  ----> Pb                3.396e-08   3.396e-08
        S                 7.624e-04   7.624e-04
        Si                1.066e-04   1.066e-04
        Zn                9.452e-06   9.452e-06
```

```
----------------------------Description of solution----------------------------

                                       pH  =   7.900
                                       pe  =  79.870
                        Activity of water  =   0.100
                           Ionic strength  =   5.565e-03
                       Mass of water (kg)  =   1.000e+00
                 Total carbon (mol/kg)  =   1.546e-03
                    Total CO2 (mol/kg)  =   1.546e-03
                      Temperature (deg C)  =  11.000
                  Electrical balance (eq)  =  -3.325e-04
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -4.60
                               Iterations  = 101
                                  Total H  = 1.110140e+02
                                  Total O  = 2.055514e+03
```

```
Pb                3.396e-08
      PbCO3                3.186e-08   3.190e-08    -7.497    -7.496     0.001
      Pb+2                 8.875e-10   6.503e-10    -9.052    -9.187    -0.135
      PbHCO3+              5.928e-10   5.485e-10    -9.227    -9.261    -0.034
      Pb(CO3)2-2           3.086e-10   2.261e-10    -9.511    -9.646    -0.135
      PbSO4                1.832e-10   1.834e-10    -9.737    -9.737     0.001
      PbOH+                1.089e-10   1.007e-10    -9.963    -9.997    -0.034
      PbCl+                2.268e-11   2.098e-11   -10.644   -10.678    -0.034
      Pb(SO4)2-2           6.589e-13   4.828e-13   -12.181   -12.316    -0.135
      Pb(OH)2              3.109e-13   3.113e-13   -12.507   -12.507     0.001
      PbCl2                5.098e-14   5.105e-14   -13.293   -13.292     0.001
      PbCl3-               4.670e-17   4.321e-17   -16.331   -16.364    -0.034
      Pb(OH)3-             3.068e-17   2.839e-17   -16.513   -16.547    -0.034
      Pb2OH+3              2.952e-18   1.466e-18   -17.530   -17.834    -0.304
      PbCl4-2              2.941e-20   2.155e-20   -19.532   -19.667    -0.135
      Pb(OH)4-2            7.049e-22   5.166e-22   -21.152   -21.287    -0.135
```

PHREEQC MODELING-RQ5

```
TITLE RQ5 initial results
SOLUTION 1
        pH 7.9
        temp 12
        pe 79.87
        units mg/L
        Alkalinity 200
        Al 0.0045
        Cd 0.00013
        Ca 69
        Cl 870
        Cu 0.0029
        Fe 0.053
        Pb 0.00077
        Mg 68
        Mn 0.028
        K 16
        Si 8.2 as SiO2
        Na 420
        S 140 as SO4-2
        Zn 0.009
EQUILIBRIUM_PHASES 1
        O2(g) -0.678
        CO2(g) -3.46
END
-----
```

```
------------------------------Solution composition------------------------------

Elements            Molality       Moles

Al                 1.573e-07    1.573e-07
Alkalinity         4.413e-03    4.413e-03
Ca                 1.664e-03    1.664e-03
Cd                 1.118e-09    1.118e-09
Cl                 2.423e-02    2.423e-02
Cu                 4.300e-08    4.300e-08
Fe                 9.006e-07    9.006e-07
K                  4.133e-04    4.133e-04
Mg                 2.704e-03    2.704e-03
Mn                 5.035e-07    5.035e-07
Na                 1.788e-02    1.788e-02
Pb                 3.588e-09    3.588e-09
S                  1.411e-03    1.411e-03
Si                 1.367e-04    1.367e-04
Zn                 1.349e-07    1.349e-07
```

```
----------------------------Description of solution----------------------------

                                       pH  =   7.900
                                       pe  =  79.870
                        Activity of water  =   0.100
                           Ionic strength  =   3.380e-02
                       Mass of water (kg)  =   1.000e+00
                 Total carbon (mol/kg)  =   5.614e-03
                    Total CO2 (mol/kg)  =   5.614e-03
                   Temperature (deg C)  =  12.000
                Electrical balance (eq)  =  -4.433e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -7.75
                               Iterations  = 101
                                  Total H  = 1.110173e+02
                                  Total O  = 2.055528e+03
```

```
Pb              3.588e-09
        PbCO3           3.301e-09   3.326e-09    -8.481    -8.478     0.003
        Pb(CO3)2-2      1.594e-10   8.178e-11    -9.798   -10.087    -0.290
        PbHCO3+         6.572e-11   5.562e-11   -10.182   -10.255    -0.072
        Pb+2            3.810e-11   1.956e-11   -10.419   -10.709    -0.290
        PbCl+           1.338e-11   1.132e-11   -10.874   -10.946    -0.072
        PbSO4           6.504e-12   6.555e-12   -11.187   -11.183     0.003
        PbOH+           3.578e-12   3.029e-12   -11.446   -11.519    -0.072
        PbCl2           4.677e-13   4.714e-13   -12.330   -12.327     0.003
        Pb(SO4)2-2      3.995e-14   2.050e-14   -13.398   -13.688    -0.290
        Pb(OH)2         9.287e-15   9.360e-15   -14.032   -14.029     0.003
        PbCl3-          8.288e-15   7.015e-15   -14.082   -14.154    -0.072
        PbCl4-2         1.201e-16   6.161e-17   -15.921   -16.210    -0.290
        Pb(OH)3-        1.009e-18   8.536e-19   -17.996   -18.069    -0.072
        Pb2OH+3         5.948e-21   1.326e-21   -20.226   -20.877    -0.652
        Pb(OH)4-2       3.027e-23   1.553e-23   -22.519   -22.809    -0.290
```

Comparison

Molarity to micrograms/L

207.2 x 3.396 x10-8=
7.04x10-6g/L
7.4micrgrams/L

----------------------------Solution compositic

Elements	Molality	Moles
Al	1.330e-06	1.330e-06
Alkalinity	1.183e-03	1.183e-03
Ca	8.810e-04	8.810e-04
Cd	1.270e-07	1.270e-07
Cl	1.262e-03	1.262e-03
Cu	2.076e-07	2.076e-07
Fe	3.441e-07	3.441e-07
K	3.592e-05	3.592e-05
Mg	4.710e-04	4.710e-04
Mn	9.670e-08	9.670e-08
Na	8.728e-04	8.728e-04
Pb	3.396e-08	3.396e-08
S	7.624e-04	7.624e-04
Si	1.066e-04	1.066e-04
Zn	9.452e-06	9.452e-06

----------------------------Solution composition-------

Elements	Molality	Moles
Al	1.573e-07	1.573e-07
Alkalinity	4.413e-03	4.413e-03
Ca	1.664e-03	1.664e-03
Cd	1.118e-09	1.118e-09
Cl	2.423e-02	2.423e-02
Cu	4.300e-08	4.300e-08
Fe	9.006e-07	9.006e-07
K	4.133e-04	4.133e-04
Mg	2.704e-03	2.704e-03
Mn	5.035e-07	5.035e-07
Na	1.788e-02	1.788e-02
Pb	3.588e-09	3.588e-09
S	1.411e-03	1.411e-03
Si	1.367e-04	1.367e-04
Zn	1.349e-07	1.349e-07

Dilution and/or Sorption onto Ferrihydrites

207.2 x 3.588 x10-9=
7.43x10-7g/L
0.74micrgrams/L

PHREEQC MODELING- Affect of changing pH on saturation of Pb-bearing minerals

```
------------------------------------
Reading input data for simulation 1.
------------------------------------

        TITLE BL6 Initial Results
        SOLUTION 1
                pH 7.9
                temp 11
                pe 79.87
                units mg/L
                Alkalinity 62
                Al 0.038
                Cd 0.015
                Ca 37
                Cl 44
                Cu 0.014
                Fe 0.02
                Pb 0.0074
                Mg 12
                Mn 0.0054
                K 1.4
                Si 6.4 as SiO2
                Na 20
                S 77 as SO4-2
                Zn 0.65
        EQUILIBRIUM_PHASES 1
                O2(g) -0.678
                CO2(g) -3.46
        END
```

```
-----------------------------Solution composition------------------------------

        Elements           Molality       Moles

        Al                1.330e-06   1.330e-06
        Alkalinity        1.183e-03   1.183e-03
        Ca                8.810e-04   8.810e-04
        Cd                1.270e-07   1.270e-07
        Cl                1.262e-03   1.262e-03
        Cu                2.076e-07   2.076e-07
        Fe                3.441e-07   3.441e-07
        K                 3.592e-05   3.592e-05
        Mg                4.710e-04   4.710e-04
        Mn                9.670e-08   9.670e-08
        Na                8.728e-04   8.728e-04
        Pb                3.396e-08   3.396e-08
        S                 7.624e-04   7.624e-04
        Si                1.066e-04   1.066e-04
        Zn                9.452e-06   9.452e-06
```

Reminder of original data from BL6 at normal conditions (pH 7.9)

Resultant Mineralogy

------------------------------Saturation indices------------------------------

Phase	SI	log IAP	log KT	
Al(OH)3(a)	-0.48	11.28	11.76	Al(OH)3
Albite	5.90	11.16	5.26	NaAlSi3O8
Alunite	1.65	2.06	0.41	KAl3(SO4)2(OH)6
Anglesite	-4.62	-12.49	-7.87	PbSO4
Anhydrite	-2.18	-6.52	-4.33	CaSO4
Anorthite	4.92	33.19	28.27	CaAl2Si2O8
Aragonite	-0.51	-8.77	-8.26	CaCO3
Ca-Montmorillonite	14.19	23.44	9.25	Ca0.165Al2.33Si3.67O10(OH)2
Calcite	-0.35	-8.77	-8.41	CaCO3
Cd(OH)2	-6.96	6.69	13.65	Cd(OH)2
CdSiO3	-3.95	5.71	9.66	CdSiO3
CdSO4	-10.85	-10.41	0.43	CdSO4
Cerrusite	-1.43	-14.74	-13.31	PbCO3
Chalcedony	1.75	-1.97	-3.72	SiO2
Chlorite(14A)	-1.65	72.20	73.85	Mg5Al2Si3O10(OH)8
Chrysotile	-6.03	27.99	34.02	Mg3Si2O5(OH)4
CO2(g)	-2.14	-20.35	-18.21	CO2
Dolomite	-1.05	-17.80	-16.75	CaMg(CO3)2
Fe(OH)3(a)	1.62	6.51	4.89	Fe(OH)3
FeS(ppt)	-742.41	-795.52	-53.11	FeS
Gibbsite	2.35	11.28	8.93	Al(OH)3
Goethite	7.99	7.51	-0.48	FeOOH
Gypsum	-3.93	-8.52	-4.59	CaSO4:2H2O
H2(g)	-175.54	-175.54	0.00	H2
H2O(g)	-2.89	-1.00	1.89	H2O
H2S(g)	-673.46	-717.26	-43.80	H2S
Halite	-7.58	-6.03	1.55	NaCl
Hausmannite	-27.96	-42.63	-14.66	Mn3O4
Hematite	18.92	16.03	-2.89	Fe2O3
Illite	12.64	26.06	13.42	K0.6Mg0.25Al2.3Si3.5O10(OH)2
Jarosite-K	-4.16	-12.24	-8.08	KFe3(SO4)2(OH)6
K-feldspar	7.26	9.78	2.51	KAlSi3O8
K-mica	19.49	34.34	14.85	KAl3Si3O10(OH)2
Kaolinite	10.90	19.61	8.71	Al2Si2O5(OH)4
Mackinawite	-741.68	-795.52	-53.84	FeS
Manganite	15.48	14.38	-1.10	MnOOH
Melanterite	-88.59	-104.36	-15.76	FeSO4:7H2O
O2(g)	261.03	349.08	88.05	O2
Otavite	-0.56	-12.66	-12.10	CdCO3
Pb(OH)2	-4.04	4.61	8.66	Pb(OH)2
Pyrite	-1233.33	-1337.24	-103.90	FeS2

Results with changed variables

Increase to pH 10

------------------------------Saturation indices------------------------------

Phase	SI	log IAP	log KT	
Al(OH)3(a)	-3.44	8.32	11.76	Al(OH)3
Albite	-2.82	2.44	5.26	NaAlSi3O8
Alunite	-16.50	-16.08	0.41	KAl3(SO4)2(OH)6
Anglesite	-6.52	-14.39	-7.87	PbSO4
Anhydrite	-2.19	-6.53	-4.33	CaSO4
Anorthite	-3.41	24.86	28.27	CaAl2Si2O8
Aragonite	1.16	-7.10	-8.26	CaCO3
Ca-Montmorillonite	-2.74	6.51	9.25	Ca0.165Al2.33Si3.67O10(OH)2
Calcite	1.31	-7.10	-8.41	CaCO3
Cd(OH)2	-0.93	12.72	13.65	Cd(OH)2
CdSiO3	-1.20	8.46	9.66	CdSiO3
CdSO4	-10.99	-10.56	0.43	CdSO4
Cerrusite	-1.66	-14.97	-13.31	PbCO3
Chalcedony	-0.54	-4.26	-3.72	SiO2
Chlorite(14A)	12.51	86.36	73.85	Mg5Al2Si3O10(OH)8
Chrysotile	6.97	40.99	34.02	Mg3Si2O5(OH)4
CO2(g)	-5.64	-23.85	-18.21	CO2
Dolomite	2.29	-14.46	-16.75	CaMg(CO3)2
Fe(OH)3(a)	1.31	19.57	18.26	Fe(OH)3
FeS(ppt)	-58.20	-97.94	-39.74	FeS
Gibbsite	-0.62	8.32	8.93	Al(OH)3
Goethite	6.68	19.57	12.89	FeOOH
Gypsum	-1.94	-6.53	-4.59	CaSO4:2H2O
H2(g)	-20.94	-20.94	0.00	H2
H2O(g)	-1.89	-0.00	1.89	H2O
H2S(g)	-63.23	-107.03	-43.80	H2S
Halite	-7.58	-6.04	1.55	NaCl
Hausmannite	-8.05	56.61	64.66	Mn3O4
Hematite	15.29	39.14	23.85	Fe2O3
Illite	-1.76	11.66	13.42	K0.6Mg0.25Al2.3Si3.5O10(OH)2
Jarosite-K	-14.35	17.68	32.03	KFe3(SO4)2(OH)6
K-feldspar	-1.46	1.06	2.51	KAlSi3O8
K-mica	2.84	17.69	14.85	KAl3Si3O10(OH)2
Kaolinite	-0.60	8.11	8.71	Al2Si2O5(OH)4
Mackinawite	-57.47	-97.94	-40.47	FeS
Manganite	-2.98	22.36	25.34	MnOOH
Melanterite	-11.78	-14.18	-2.40	FeSO4:7H2O
O2(g)	-46.17	41.88	88.05	O2
Otavite	0.96	-11.14	-12.10	CdCO3
Pb(OH)2	0.23	8.88	8.66	Pb(OH)2
Pyrite	-93.50	-184.03	-90.53	FeS2

Precipitation!

Decrease to pH 6

------------------------------Saturation indices------------------------------

Phase	SI	log IAP	log KT	
Al(OH)3(a)	-0.88	10.88	11.76	Al(OH)3
Albite	-3.39	1.87	5.26	NaAlSi3O8
Alunite	3.18	3.60	0.41	KAl3(SO4)2(OH)6
Anglesite	-3.39	-11.25	-7.87	PbSO4
Anhydrite	-2.15	-6.48	-4.33	CaSO4
Anorthite	-5.65	22.62	28.27	CaAl2Si2O8
Aragonite	-2.36	-10.62	-8.26	CaCO3
Ca-Montmorillonite	2.98	12.23	9.25	Ca0.165Al2.33Si3.67O10(OH)2
Calcite	-2.21	-10.62	-8.41	CaCO3
Cd(OH)2	-8.75	4.90	13.65	Cd(OH)2
CdSiO3	-8.73	0.93	9.66	CdSiO3
CdSO4	-10.81	-10.38	0.43	CdSO4
Cerrusite	-2.09	-15.39	-13.31	PbCO3
Chalcedony	-0.25	-3.97	-3.72	SiO2
Chlorite(14A)	-21.35	52.50	73.85	Mg5Al2Si3O10(OH)8
Chrysotile	-16.37	17.65	34.02	Mg3Si2O5(OH)4
CO2(g)	-1.21	-19.42	-18.21	CO2
Dolomite	-4.76	-21.51	-16.75	CaMg(CO3)2
Fe(OH)3(a)	0.52	18.78	18.26	Fe(OH)3
FeS(ppt)	-79.71	-119.45	-39.74	FeS
Gibbsite	1.95	10.88	8.93	Al(OH)3
Goethite	5.89	18.78	12.89	FeOOH
Gypsum	-1.89	-6.48	-4.59	CaSO4:2H2O
H2(g)	-27.32	-27.32	0.00	H2
H2O(g)	-1.89	-0.00	1.89	H2O
H2S(g)	-80.77	-124.57	-43.80	H2S
Halite	-7.59	-6.04	1.55	NaCl
Hausmannite	-22.93	41.74	64.66	Mn3O4
Hematite	13.72	37.56	23.85	Fe2O3
Illite	0.75	14.17	13.42	K0.6Mg0.25Al2.3Si3.5O10(OH)2
Jarosite-K	-4.73	27.30	32.03	KFe3(SO4)2(OH)6
K-feldspar	-2.03	0.48	2.51	KAlSi3O8
K-mica	7.40	22.25	14.85	KAl3Si3O10(OH)2
Kaolinite	5.11	13.82	8.71	Al2Si2O5(OH)4
Mackinawite	-78.98	-119.45	-40.47	FeS
Manganite	-6.87	18.47	25.34	MnOOH
Melanterite	-7.77	-10.16	-2.40	FeSO4:7H2O
O2(g)	-33.41	54.64	88.05	O2
Otavite	-2.42	-14.52	-12.10	CdCO3
Pb(OH)2	-4.63	4.03	8.66	Pb(OH)2
Pyrite	-126.17	-216.70	-90.53	FeS2

Results/ Conclusion

- The Lead contamination is below the WHO limits (far below the Italian limit), therefore not a significant problem
- Arsenic is the polluted which needs filtering from the surface water (which we've already heard about from previous presentations)
- pH affects the SI's of different Pb-bearing compounds differently. $Pb(OH)_2$ and Cerrusite become more saturated with an increase in pH, the opposite affect on Anglesite is observed.
- A dramatic change in pH would be needed for any significant affect on saturation of Pb in the surface water. Natural variation in the river ranges from 7.0 to 8.0

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