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R

Deborah S. Bass

20-1402-561

Initial Entries:

Record of EQ3/6 Runs

Purpose 4/6/98

To support the CNWRA ~~characterize~~ effort to characterize the near field environment of Yucca Mountain, Nevada. To examine the equilibrium solubilities of stoichiometric minerals that contain radioactive elements in groundwaters characteristic of Yucca Mountain, Nevada.

The documentation and work is being charged to account 20-1402-561.

This notebook will be maintained by Deborah S. Bass, a limited-term employee, who is working part-time for the CNWRA and primarily funded by SwRI Division 15.

4/6/98

Procedure

Calculations of the solubilities of radioactive nuclides in representative Yucca Mountain, NV groundwaters will be accomplished by using the thermodynamic data base associated with the EQ3/6 software package (data0.com.R7, 29-oct-90). EQ3/6 was developed at Lawrence Livermore National Laboratory partially in support of the Department of Energy high-level nuclear waste disposal program (e.g., Wolery, 1979; 1983; Wolery et al., 1990; Wolery, 1992). DB 4/6/98

Wolery, T.J. (1979) Calculation of chemical equilibrium between aqueous solution and minerals: The EQ3/6 software package. Lawrence Livermore National Laboratory UCRL-52658.

Wolery, T.J. (1983) EQ3NR a computer program for geochemical aqueous speciation-solubility calculations: User's guide and documentation. Lawrence Livermore National Laboratory UCRL-53414.

Wolery, T.J., Jackson, K.J., Bourcier, W.L., Bruton, C.J., Viani, B.E., Knaus, K.G., and Delany, J.M. (1990) Current status of the EQ3/6 software package for geochemical modeling. In Melchior, D.C. and Bassett, R.L. (eds.) Chemical Modeling of Aqueous Systems II. American Chemical Society Symposium series 416. DB 4/6/98

Wolery, T.J. (1992) EQ3/6, a software package for geochemical modeling of aqueous systems: package overview and installation guide (Version 7.0). Lawrence Livermore National Laboratory, UCRL-MA-110662-pt.I. 66 pp. DB 4/6/98

DB 4/6/98

Calculations will involve a suite of representative waters from Yucca Mountain, NV and a suite of minerals that contain radioactive nuclides to determine the distribution of solubilities of the radioactive species. Of special note will be correlations/co-varience of radioactive nuclides.

Waters that will be examined:

1. J13: Water from well J-13 at the Nevada Test Site. The composition is based on data reported by Harrar et al. [1990]. Water from this well is commonly used to represent the groundwater at the proposed high-level nuclear waste repository at Yucca Mountain, Nevada. Data for Sr, Ba, Ti, P and V were obtained from Department of Energy [1988] and Daniels et al. [1982]. Charge balance on HCO_3^-

Department of Energy (1988) Site characterization plan Yucca Mountain site, Nevada research and development area, Nevada. DOE/RW-0199.

Daniels, W.R. and 21 co-authors [1982] Summary report on the geochemistry of Yucca Mountain and environs. Los Alamos National Laboratory LA-9328-MS.

2. EJ13: Equilibrated water from well J-13 at the Nevada Test Site. The water has been equilibrated with core samples from the Topopah Springs member of the Paintbrush Tuff by soaking 10 g of crushed tuff in 1 L of water at 90°C for 2 weeks. Data from Wronkiewicz et al. (1992) Charge balance on HCO_3^- DB 4/6/98

Wronkiewicz, D.J., J.K. Bates, T.J. Gerding, E. Veleckis, B. Tani (1992) Uranium release and secondary phase formation during unsaturated testing of UO_2 at 90°C. J. of Nuc. Mat., 190, 107-127.

DB 5/19/98

DB 5/28/98
~~Minerals that will control the solubilities of the radioactive nuclides:~~ Waters (continued):

3. NRG-6/160.8-161.2/PTn/BT: Pore/ground water from borehole NRG-6, Yucca Mountain, NV. Sample from nonwelded, bedded Paintbrush tuff. Reference: Symbol 'B' in Table 3, Yang et al [1996]
Yang, C., P. Yu, G.W. Rattray, D.C. Thorstenson (1996) Hydrochemical investigations and geochemical modeling in characterizing the unsaturated zone at Yucca Mt., NV, USGS, Water-Resources Investigations Report, Denver, CO.
Charge balance on HCO_3^-
4. NRG-6/171.0-171.3/PTn/BT: See water #3 for reference. Symbol 'C' in Table 3, Yang et al [1996].
Charge balance on HCO_3^-
5. NRG7A/165.8-166.0/PTn/BT: Pore/ground water from borehole NRG-7A, Yucca Mt, NV. See water #3 for reference. Symbol 'H' in Table 3, Yang et al. [1996]
Charge Balance on HCO_3^-
6. SD-9/1452.6-1452.8/TSw: Pore/ground water from borehole USW SD-9, Yucca Mountain, NV. Sample from Topopah Spring Tuff. See #3 for reference. DB Symbol '3' in Table 4, Yang et al. [1996]. 5/28/98
Charge balance on HCO_3^-
7. SD-9/1800.8/CHn/BT: Pore/ground water from borehole USW SD-9, Yucca Mt., NV. Sample from Calico Hills, nonwelded, bedded tuff. See water #3 for reference. Symbol '9' in Table 4, Yang et al. [1996].
Charge balance on HCO_3^-
8. USW UZ-14A: Perched water from borehole USW UZ-14A, Yucca Mt, NV. Yang et al [1996] Water Resources Investigations Report 96-4058. Symbol 'C' in Table 6.
Charge Balance on HCO_3^-
9. USW SD-7(3/21): Perched water from borehole USW SD-7(3/21), Yucca Mt, NV. See water #8 for reference. Symbol 'SD7(3/21)' in Table 6.
Charge balance on HCO_3^-

Continued on Page 6.

DB 5/28/98

Limitations of method:

- The thermodynamics data are uncertain for both mineral dissolution reactions and critical aqueous speciation reactions.
- Metastable supersaturations can persist indefinitely in low-temperature water-rock systems. Dissolution of primary nuclear waste forms can generate aqueous solutions that are supersaturated with respect to the most stable radioelement-bearing solids. Therefore, minimum equilibrium solubilities do not give conservatively low radioelement concentrations.
- The detailed geochemical environment at Yucca Mountain, on which equilibrium solubilities depend, is incompletely constrained.

Concurrent equilibrium coprecipitation (solid solution) of radioelements in solids composed dominantly or partially of other species and/or sorption of radioelements on solid surfaces would lead to equal or lower total aqueous solution concentrations for radioelements. Radioelement concentrations calculated in this manner represent maximum equilibrium concentrations for the given conditions and thus yield a degree of conservatism.

DB 4/6/98

Input Waters (continued from Page 4):

10. SHT Hole 16: Water from single heater test hole 16, Yucca Mt, NV.
Reference: 'SHT Hole 16 LLNL Data' in Table labeled 'Chemical Analysis of 16-4 Water' from: Update of Evolution of the Near-Field Environment (ENFE) KTI Yucca Mountain Team Briefing' 3/19/97 Bret Leslie

11. Tuff Pore Water: Model water chosen because it is in equilibrium with the chosen representation of host rock minerals.
Reference: 'Tuff Pore Water' in Table 4, Lichtner et al [1998].

Lichtner, P.C., Pabalan, R.T., Steefel, C.I. (1998), Model Calculations of Porosity Reduction Resulting from Cement-Tuff Diffusive Interaction, in Scientific Basis For Nuclear Waste Management XXI, McKinley & McCombie, eds. p. 709-718.

Charge balance on Na^+

12. Cement Pore Water: Water in representative concrete invert and lining for proposed high-level radioactive waste geologic repository at Yucca Mountain, NV.
Reference: 'Cement Pore Water' in Table 4, Lichtner et al [1998]
See water #11 for reference.

Charge balance on ~~Na^+~~ DB 6/10/98 HCO_3^-

Values for water #11, 12 are for total molality for ions & compounds containing those ions as follows:

	Tuff Pore Water	Cement Pore Water
Ca^{2+}	2.56E-04	9.23E-03
Mg^{2+}	1.65E-05	1.64E-08
Na^+	4.15E-03	2.78E-02
K^+	6.50E-05	4.10E-03
CO_3^{2-}	2.78E-03	9.32E-06
SO_4^{2-}	1.77E-04	4.65E-05
Al^{3+}	1.97E-08	2.5~~3~~4E-06 (DB)
$SiO_2(aq)$	1.91E-04	5.41E-05
Cl^-	1.63E-03	7.48E-03

/DB 6/9/98

continued page 8

Minerals controlling radioelement solubilities:

BASE CASE

Radioelement:	Mineral Phase (composition):	Alternates
Sr^{2+}	Strontianite	
Sn^{2+}	Cassiterite	
Pb^{2+}	Cerussite	
Ra^{2+}	$RaSO_4$	
Th^{4+}	Thorianite	
UO_2^{2+}	Soddyite	Haiweeite
Np^{4+}	NpO_2	$NpO_2(OH)_2(am)$ (DB)
Am^{3+}	$Am_2(CO_3)_3$	$AmPO_4(am)$
no Ni		
Pu^{4+}	PuO_2	$PuO_2(OH)_2$

All waters run without radioelements. Then base case radioelements & mineral phases controlling those solubilities were added. Then substitutions for base case as follows:

1. Waters
2. Waters w/ base case
3. Waters w/ $PuO_2(OH)_2$ substituting for PuO_2 control on Pu^{4+}
4. Waters w/ $AmPO_4(am)$ sub. for $Am_2(CO_3)_3$ *only #1 (J13) DB 7/2/98
5. Waters w/ $NpO_2OH(am)$ sub. for NpO_2
6. Waters w/ Haiweeite (DB) sub. for soddyite
7. Waters w/ $PuO_2(OH)_2$ and $AmPO_4(am)$ *only #1 (J13) DB 7/2/98
8. Waters w/ $PuO_2(OH)_2$ and $NpO_2OH(am)$
9. Waters w/ $PuO_2(OH)_2$ and Haiweeite
10. Waters w/ $PuO_2(OH)_2$ and $AmPO_4(am)$ and $NpO_2OH(am)$ *only #1 DB
11. Waters w/ $PuO_2(OH)_2$ and $AmPO_4(am)$ and Haiweeite *only #1 DB
12. Waters w/ $AmPO_4(am)$ and $NpO_2OH(am)$ *only #1 (J13) DB 7/2/98
13. Waters w/ $AmPO_4(am)$ and Haiweeite *only #1 (J13) DB 7/2/98
14. Waters w/ $AmPO_4(am)$ and $NpO_2OH(am)$ and Haiweeite *only #1 *
15. Waters w/ $NpO_2OH(am)$ and Haiweeite
16. Waters w/ $NpO_2OH(am)$ and Haiweeite and $Pu_2(OH)_2$ and $AmPO_4(am)$ *only #1 (J13) DB 7/2/98
17. Waters w/ $NpO_2OH(am)$ and Haiweeite and $Pu_2(OH)_2$

Input Waters (continued from Page 6):

13. NRG-6/158.2-158.6/PTn/BT: Pore/ground water from borehole NRG-6, Yucca Mountain, NV. See water #3 for reference. Symbol 'A' in Table 3, Yang et al. [1996].
Charge balance on HCO_3^-

14. NRG-7A/258.0-258.4/PTn/BT: Pore/ground water from borehole NRG-7A, Yucca Mountain, NV. See water #3 for reference. Symbol 'I' in Table 3, Yang et al [1996]
Charge balance on HCO_3^-

15. SD-12/265.8-266.1/PTn/BT: Pore/ground water from borehole SD-12, Yucca Mountain, NV. See water #3 for reference. Symbol 'A' in Table 4, Yang et al. [1996].
Charge balance on HCO_3^-.

~~16. SD UZ-14/1865.9-1865.9 1865.9~~ DB 7/7/98

16. UZ-14/1865.7-1865.9/CHn/PP: Pore/ground water from borehole USW UZ-14, Yucca Mountain, NV. See water #3 for reference. Sample from Calico Hills nonwelded Prow Pass tuff. Symbol 'c' in Table 2, Yang et al. [1996].
Charge balance on HCO_3^-.

17. USW UZ-14B: Perched water from borehole USW UZ-14B, Yucca Mountain, NV. See water #8 for reference. Symbol 'E' in Table 6.
Charge balance on HCO_3^-.

18. UE-25 UZ#16/1408.2-1408.6: Pore/ground water from borehole UE-25 UZ#16, Yucca Mt., NV. See water #8 for reference. Symbol 'H' in Table 2.
Charge balance on HCO_3^-

DB 7/7/98

19. J13-98: Fracture-water from well J-13 at the NTS. Composition is based on data from Harrar et al [1990]. This exact composition is from Near-Field/Altered-Zone Models Report UCRL-ID-129179. Table 6-1, page 6-6.
Charge balance on H^+
Quartz, tridymite, talc suppressed.
Hardin, E.L., Near-Field/Altered-Zone Models Report, SP3100M3 WBS1.2.3, Lawrence Livermore National Laboratories, March 1998. UCRL-ID-129179.

20. Rainer Mesa: Fracture-water from Rainer Mesa. Composition is based on data from Harrar et al. [1990]. Composition from Near-Field/Altered-Zone Models Report, Table 6-1. See #19 water for reference.
Charge balance on H^+, qtz, trid, talc suppressed.

~~21. SHT-16-98: Fracture-water from single heater test hole #16 from Yucca Mountain, NV. See water #19 for reference. Table 6-1. Composition based on Glassley & Deloach [1997].~~

~~Charge balance on H^+~~
~~Qtz, tridymite, talc suppressed.~~

DB 9/28/98

21. Model15-~~25~~ 95: Fracture-water from model. Composition is based on Lin et al [1995] model, 15m depth, 45yrs and ~~25~~ 95°C. See water #19 for reference, table 6-1.
Charge balance on H^+, quartz, trid, talc suppressed.

(95 DB 9/28/98)

22. Model1.5-~~25~~ 95: Fracture-water from model. Composition is based on Lin et al. [1995] model, 1.5m depth, 5 months and ~~25~~ 95°C. See water #19 for reference, Table 6-1.
Charge balance on H^+, qtz, trid, talc suppressed.

(95 DB 9/28/98)

23. Model15-95: Fracture-water from model. Composition is based on Lin et al. [1995] model, 15 m depth, 45yrs and 95°C. See water #19 for reference, Table 6-1.
Charge balance on H^+, qtz, trid, talc suppressed

DB 9/28/98

Summary of Wates & Resulting Radionuclide Concentrations (in Molality). 11/18/98

Tables of concentrations created in Excel.

each table contains all waters and one suite of minerals that controls the solubility of the radioelements.

For example : Base case water

Radio-element	Mineral phase	Alternate
Am	$Am_2(CO_3)_3$	$AmPO_4$ (amorph.)
Np	NpO_2	$NpO_2(OH)$ (amorp)
Pb	Cerussite	
Pu	PuO_2	$PuO_2(OH)_2$
Ra	$RaSO_4$	
Sn	Cassiterite	
Sr	Strontianite	
Th	Thorianite	
U	Soddyite	Haiweeite

See facing page 11 for sample.

DB 4/8/99

pH, Temperature and total carbon concentration added. 4/8/99 DB

Sheet1

	Am	Np	Pb	Pu	Ra	Sn	Sr	Th	UO2	VO
CPW	1.59E-01	1.29E-07	3.63E-11	1.77E-10	5.26E-06	2.68E-08	4.53E-08	6.71E-15	1.81E-03	N/A
NRG6-A	9.07E-06	4.72E-05	3.71E-07	2.57E-12	5.29E-08	2.00E-08	3.43E-04	4.97E-15	1.74E-08	N/A
NRG6-B	4.07E-06	1.19E-05	1.29E-07	7.03E-13	5.45E-08	2.00E-08	1.20E-04	4.92E-15	8.97E-09	N/A
NRG6-C	2.28E-06	1.05E-05	6.26E-08	1.06E-12	7.62E-08	2.25E-08	5.64E-05	5.60E-15	2.71E-08	N/A
NRG7A-H	1.58E-06	5.67E-06	3.05E-08	7.42E-13	9.48E-08	2.12E-08	2.80E-05	5.24E-15	2.69E-08	N/A
NRG7A-I	6.24E-07	9.88E-07	2.03E-09	1.19E-12	9.36E-08	2.12E-08	1.87E-06	5.24E-15	1.98E-07	N/A
SD12-A	2.00E-06	6.58E-06	4.73E-08	6.28E-13	1.23E-07	2.25E-08	4.14E-05	5.60E-15	1.82E-08	N/A
SD7-21	6.20E-07	9.96E-07	2.39E-09	9.48E-13	5.06E-07	2.42E-08	2.02E-06	6.04E-15	1.20E-07	N/A
SD9-3	8.16E-07	3.11E-06	9.23E-09	2.22E-12	1.15E-07	2.87E-08	7.47E-06	7.22E-15	1.74E-07	N/A
SD9-9	1.65E-06	1.69E-06	1.11E-10	4.61E-12	4.37E-07	3.23E-08	9.87E-08	8.20E-15	1.77E-05	N/A
SHT-16	4.86E-06	5.24E-05	2.74E-07	7.38E-12	3.14E-06	2.70E-08	2.15E-04	6.84E-15	9.64E-08	N/A
TPW	5.86E-07	1.03E-06	2.19E-09	1.45E-12	3.86E-07	2.70E-08	1.72E-06	6.77E-15	5.42E-07	N/A
UZ14-e	6.06E-07	8.54E-07	6.68E-10	2.48E-12	6.76E-07	3.63E-08	4.78E-07	9.31E-15	1.71E-06	N/A
UZ14A-C	8.40E-07	2.31E-06	9.36E-09	1.19E-12	4.89E-07	3.06E-08	7.04E-06	7.74E-15	1.19E-07	N/A
UZ14B-E	6.17E-07	1.18E-06	2.82E-09	1.24E-12	3.76E-07	2.51E-08	2.34E-06	6.27E-15	1.68E-07	N/A
UZ16-H	1.01E-06	6.55E-07	2.17E-10	1.45E-12	4.02E-07	2.70E-08	1.88E-07	6.77E-15	1.62E-06	N/A
ej13	7.38E-07	1.89E-07	6.85E-09	1.46E-12	3.06E-06	1.45E-06	1.30E-06	2.47E-12	3.34E-08	N/A
j13	1.88E-06	1.09E-05	5.10E-08	1.82E-11	3.28E-07	2.70E-08	4.08E-05	1.67E-14	5.14E-08	5.70E-07
model1.5-95	N/A	1.40E-07	8.88E-08	3.22E-12	N/A	2.06E-06	1.44E-05	5.43E-12	2.16E-09	N/A
model15-25	N/A	1.12E-07	1.28E-10	3.91E-12	N/A	2.70E-08	1.17E-07	6.77E-15	1.35E-06	N/A
model15-95	N/A	1.60E-07	2.44E-08	3.24E-12	N/A	2.06E-06	4.03E-06	5.43E-12	4.25E-09	N/A
rainer	N/A	3.48E-07	2.02E-10	4.77E-13	N/A	2.70E-08	1.76E-07	6.77E-15	3.71E-07	N/A

3/5/99

Note to: Bill Murphy
Bret Leslie

From: Richard Codell

Subject: Correlation of solubilities

I took the solubilities provided by Bill Murphy from multiple runs of EQ3/EQ6 and determined correlations among them. If there were correlations, then this should be built into the sampling in the TPA code so that a change in one element was reflected in changes in the other elements.

Figures 1 and 2 are scatter plots for the raw solubilities and the logarithms of the solubilities, respectively. The logarithms show any correlations more clearly.

Figures 3 and 4 are the Pearson "r" correlation factors for the raw solubilities and the logarithms of the solubilities, respectively. Also included are probability factors for each r that determine whether correlations are significant. This statistical test assumes that for the null hypothesis that two variables are uncorrelated, and if the number of samples N is large, that r will be approximately normally distributed with a mean of zero and a standard deviation of $1/\sqrt{N}$. The probability that the absolute value of r is greater than zero is:

$$erfc\left(|r|\sqrt{N/2}\right)$$

A small value indicates that the correlation is high. This statistical test may not always be appropriate for the correlations here because the number of samples is on the order of 100, and in some cases smaller. It also might not be useful unless there is a straight line correlation between two solubilities or their logs. The scatter plots in Figures 1 and 2 show that in some cases the correlations are not linear. I used the probability criteria to specify which correlations were significant and circled them in Figures 3 and 4.

The next step would be to include the significant correlations into TPA runs. It appears there are clearer correlations for the logs of the solubilities, but I am not sure how to include them into the sampling routine since the log solubility is not the one being sampled. From an inspection of the results, it does not appear that the correlations would make a great difference at 10,000 years since those doses are dominated by radionuclides such as iodine and technicium. For 50,000 years, neptunium, americium and uranium take on greater importance, but the only likely correlation that appears in these results would be Np-Am and Am-UO_2.

I will do more when I return on March 15, 1999.

Dick Codell

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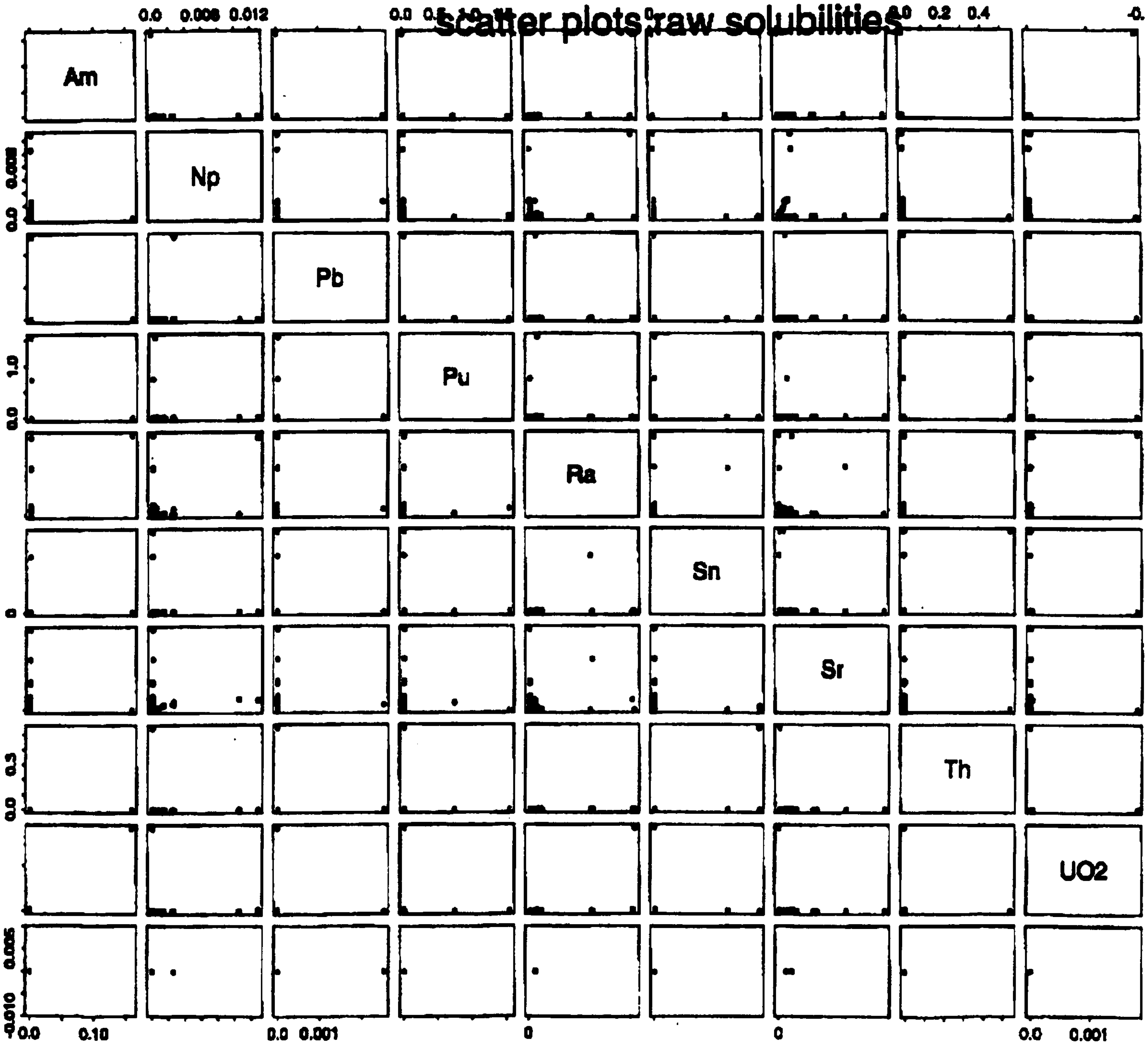
scatter plots raw solubilities
Am
Np
Pb
Pu
Ra
Sn
Sr
Th
UO2
0.0
0.006
0.012
0.2
0.4
0.10
0.001
1.0
0.3
0.005
0.010
0

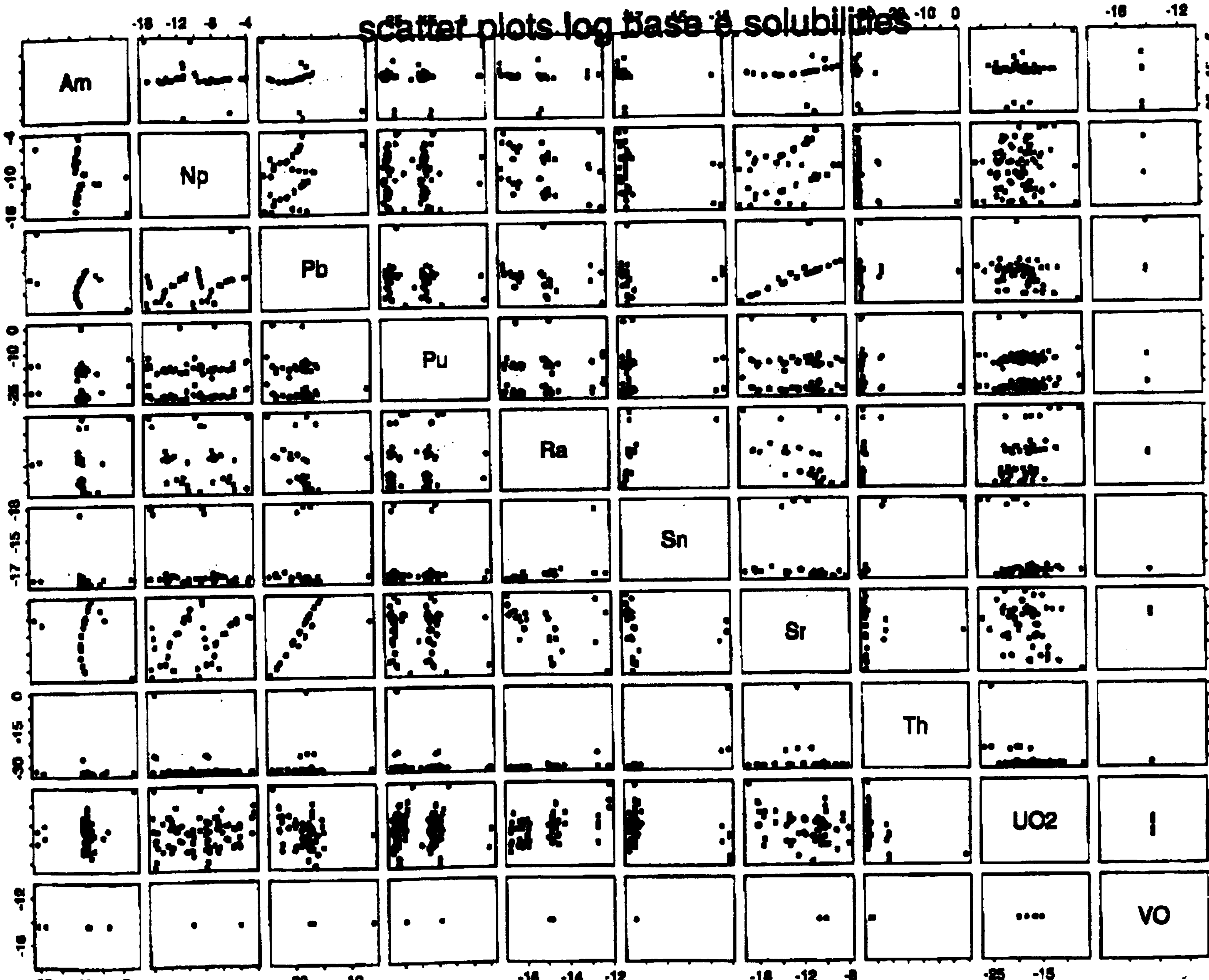
scatter plots log base e solubilities
Am
Np
Pb
Pu
Ra
Sn
Sr
Th
UO2
VO

Figure 3 – Correlation and ... for raw solubilities

n= 186

r for raw solubilities

	Am	Np	Pb	Pu	Ra	Sn	Sr	Th	UO2	VO
Am	1.000	-0.063	-0.014	-0.018	0.586	-0.039	-0.080	-0.019	1.000	0.092
Np	-0.063	1.000	0.057	-0.025	[illegible]	[illegible]	0.037	-0.026	-0.048	0.000
Pb	-0.014	0.057	1.000	-0.008	-0.026	-0.027	-0.007	-0.006	-0.012	0.071
Pu	-0.018	-0.025	-0.008	1.000	-0.036	-0.036	-0.030	-0.007	-0.015	[illegible]
Ra	0.586	0.227	-0.026	-0.036	1.000	[illegible]	0.065	-0.069	0.589	0.982
Sn	-0.039	-0.121	-0.027	-0.036	0.431	1.000	[illegible]	[illegible]	-0.055	0.000
Sr	-0.080	0.037	-0.007	-0.030	0.065	-0.126	1.000	-0.028	-0.067	0.736
Th	-0.019	-0.026	-0.006	-0.007	-0.069	0.232	-0.028	1.000	-0.011	-0.999
UO2	1.000	-0.048	-0.012	-0.015	0.589	-0.055	-0.067	-0.011	1.000	[illegible]
VO	0.092	0.000	0.071	0.207	0.982	0.000	0.736	-0.999	0.273	1.000

prob for raw solubilities

	Am	Np	Pb	Pu	Ra	Sn	Sr	Th	UO2	VO
Am	0.000	0.981	0.999	0.998	0.010	0.992	0.969	0.998	0.000	0.986
Np	0.981	0.000	0.983	0.997	0.749	0.921	0.993	0.996	0.988	1.000
Pb	0.999	0.983	0.000	1.000	0.997	0.996	1.000	1.000	0.999	0.992
Pu	0.998	0.997	1.000	0.000	0.994	0.993	0.995	1.000	0.999	0.928
Ra	0.010	0.749	0.997	0.994	0.000	0.213	0.980	0.977	0.009	0.000
Sn	0.992	0.921	0.996	0.995	0.213	0.000	0.915	0.713	0.984	1.000
Sr	0.969	0.995	1.000	0.995	0.980	0.915	0.000	0.996	0.976	0.108
Th	0.998	0.996	1.000	1.000	0.977	0.713	0.996	0.000	0.999	0.000
UO2	0.000	0.988	0.999	0.999	0.009	0.984	0.976	0.999	0.000	0.873
VO	0.986	1.000	0.992	0.928	0.000	1.000	0.108	0.000	0.873	0.000

Figure 4

correlation coefficients r for logs

	Am	Np	Pb	Pu	Ra	Sn	Sr	Th	UO2	VO
Am	1.000	-0.160	0.000	0.000	0.000	-0.061	0.000	0.000	0.000	0.000
Np	-0.160	1.000	0.319	0.016	-0.200	[illegible]	0.362	-0.237	0.073	0.000
Pb	0.000	0.319	1.000	-0.005	[illegible]	0.139	[illegible]	0.252	-0.412	-0.380
Pu	0.000	0.016	-0.003	1.000	-0.033	[illegible]	-0.020	0.043	0.023	-0.237
Ra	0.000	-0.200	-0.396	-0.033	1.000	0.525	[illegible]	-0.466	0.490	1.000
Sn	-0.061	-0.265	0.139	0.044	0.525	1.000	-0.060	0.797	-0.347	0.000
Sr	0.000	0.362	0.881	-0.020	-0.249	-0.060	1.000	-0.026	-0.312	[illegible]
Th	0.000	-0.237	0.252	0.043	-0.466	0.797	-0.026	1.000	[illegible]	[illegible]
UO2	0.000	0.073	-0.412	0.023	0.490	-0.347	-0.312	-0.397	1.000	[illegible]
VO	0.000	0.000	-0.380	-0.237	1.000	0.000	0.947	-0.998	0.848	1.000

prob for log solubilities

	Am	Np	Pb	Pu	Ra	Sn	Sr	Th	UO2	VO
Am	0.000	0.875	1.000	1.000	1.000	0.992	1.000	1.000	1.000	1.000
Np	0.875	0.000	0.476	0.999	0.805	0.681	0.349	0.700	0.972	1.000
Pb	1.000	0.476	0.000	1.000	0.303	0.897	0.000	0.660	0.213	0.748
Pu	1.000	0.999	1.000	0.000	0.995	0.998	0.998	0.990	0.997	0.905
Ra	1.000	0.805	0.303	0.995	0.000	0.050	0.697	0.135	0.094	0.000
Sn	0.992	0.681	0.897	0.998	0.050	0.000	0.981	0.000	0.393	1.000
Sr	1.000	0.349	0.000	0.998	0.697	0.981	0.000	0.996	0.493	0.000
Th	1.000	0.700	0.660	0.990	0.135	0.000	0.996	0.000	0.252	0.000
UO2	1.000	0.972	0.213	0.997	0.094	0.393	0.495	0.252	0.000	0.009
VO	1.000	1.000	0.748	0.905	0.000	1.000	0.000	0.000	0.009	0.000

Final Entry

I Have reviewed this notebook. It complies with QAP-001. There is sufficient information for another qualified person to reproduce the work.

D. C. D[illegible]

9/1/2000

[illegible]

9/1/2000

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