

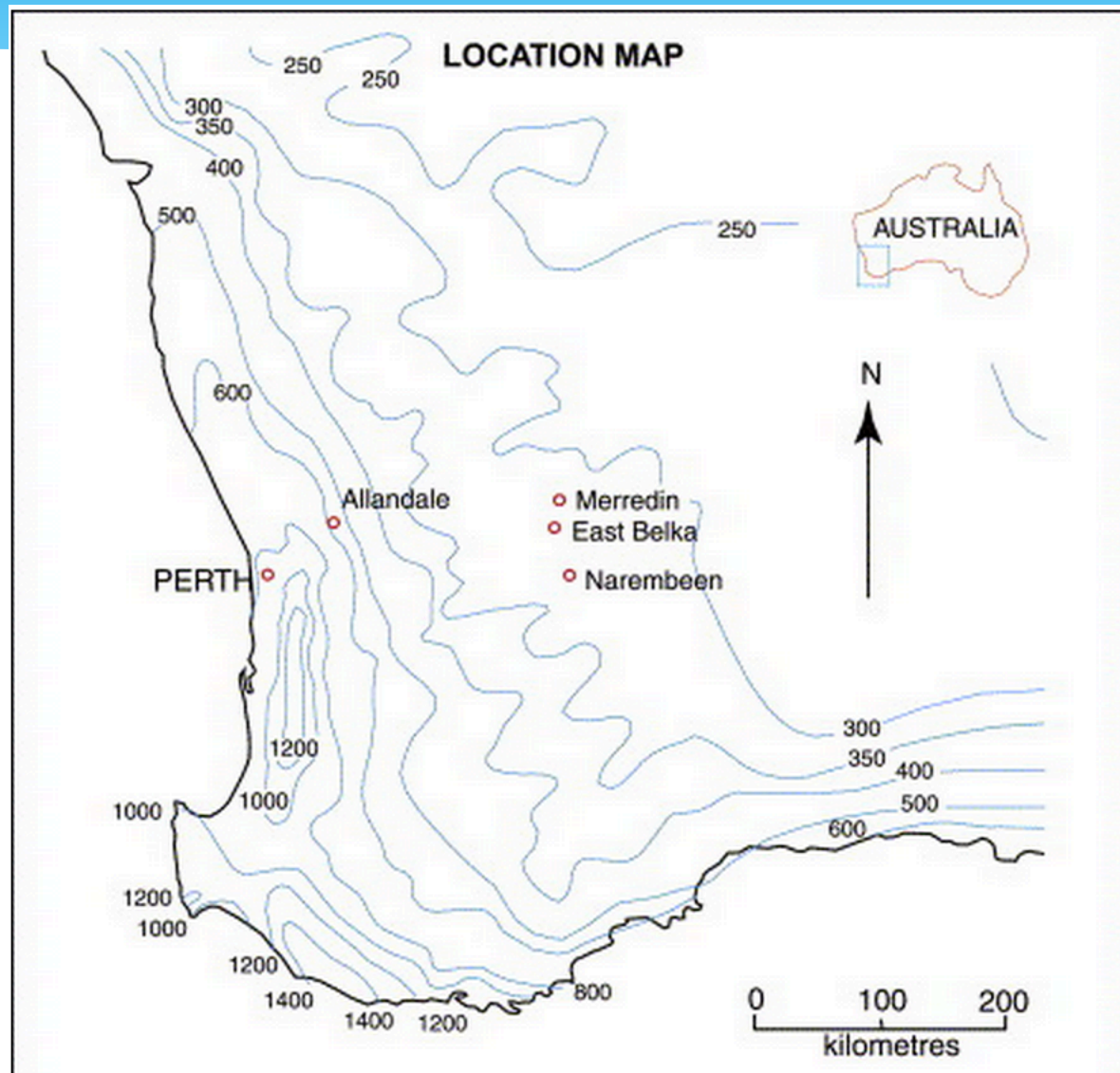
Groundwater Geochemistry and the Seasonal Effect of Deposition in Hardpans in Allandale, Australia

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Outline

- * Introduction
- * Background Information
- * Original Study
- * Seasonal differences
- * Results
- * Future Possibilities
- * References
- * Questions

Background



Silcrete

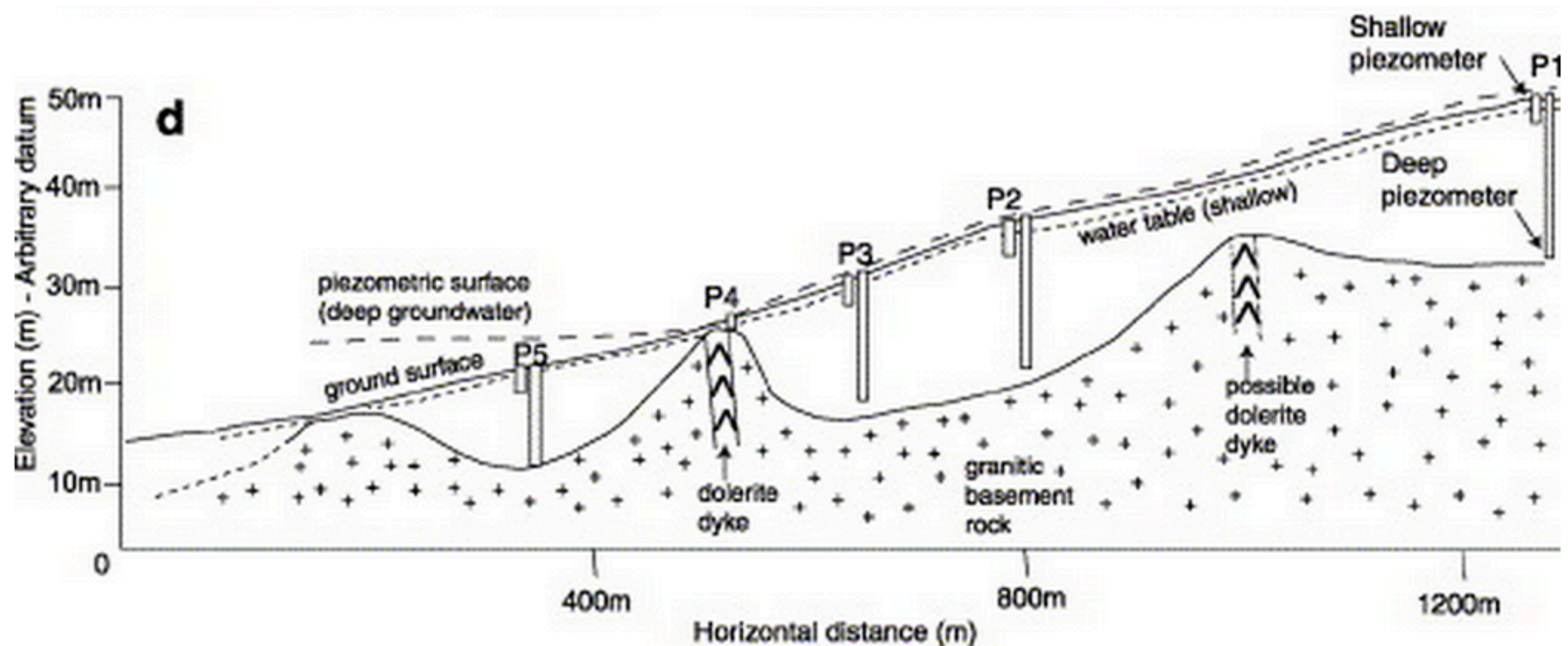
- * Water table risen up to 30 meters
- * Allandale 600 mm rain/year
- * Other 420-289 mm
- * Fargo – 540 mm



Background



Background



Original Study

Allandale Piezometer	Date collected (month– year)	pH	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	Si (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)	Ba (mg/l)	SO ₄ (mg/l)	Cl (mg/l)	TDS (mg/l)
P1-S	Apr–01	4.6	62	533	2	2400	6	0.35	107.00	0.50	2.82	151	5788	9053
P1-D	Apr–01	3.2	185	760	18	2850	77	6.38	0.43	2.50	1.92	139	7536	11576
P3-D	Apr–01	4.5	125	620	16	2600	41	0.00	0.00	0.60	n/a	127	6760	10290
P5-S	Apr–01	4.1	183	528	14	2450	59	1.57	3.60	3.00	1.90	136	6255	9635
P5-D	Apr–01	5.4	182	500	19	2125	75	0.32	0.05	2.30	2.01	125	5052	8083

April Results

Mineral phase	P1-D	P1-S	P3-D	P5-D	P5-S
Al(OH) ₃ (a)	-5.94	-2.99	****	-1.02	-3.79
Albite	****	****	****	0.82	-3.55
Alunite	-4.31	-0.41	****	4.09	-0.59
Barite	0.9	1.21	n/a	1.05	0.97
Chalcedony	0.72	-0.4	0.45	0.72	0.59
Fe(OH) ₃ (a)	****	****	****	-2.96	****
Gibbsite	-3.23	-0.29	****	1.7	-1.09
Goethite	-4.94	3.1	****	2.94	-0.38
Gypsum	-1.96	-2.29	-2.08	-1.87	-1.88
Hematite	****	****	****	****	1.16
Illite	****	****	****	4.05	-4.27
Jarosite	****	****	****	****	****
K-feldspar	****	****	****	1.13	-3.45
K-mica	****	-0.95	****	****	-0.02
Kaolinite	-3.33	0.3	****	****	0.69
Quartz	1.13	0.01	0.87	1.13	1
SiO ₂ (a)	-0.13	-1.25	-0.4	-0.14	-0.25

Would seasonal variations affect the system?

- * Future studies
- * pH values
- * Same water composition

			Ca	Mg	K	Na	Si	Al	Fe	Mn	Ba	SO ₄	Cl	TDS
			(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
P1-S	Aug-01	3.9	62	533	2	2400	6	0.35	107.00	0.50	2.82	151	5788	9053
P1-D	Aug-01	3.8	185	760	18	2850	77	6.38	0.43	2.50	1.92	139	7536	11576
P3-D	Aug-01	4.4	125	620	16	2600	41	0.00	0.00	0.60	n/a	127	6760	10290
P5-S	Aug-01	4.8	183	528	14	2450	59	1.57	3.60	3.00	1.90	136	6255	9635
P5-D	Aug-01	5.3	182	500	19	2125	75	0.32	0.05	2.30	2.01	125	5052	8083

Output S1

Mineral phase	P1-D	P1-S	P3-D	Phase	SI	log IAP	log KT	
Al(OH) ₃ (a)	-5.94	-2.99	****	Al(OH) ₃ (a)	-4.94	5.86	10.80	Al(OH) ₃
Albite	****	****	****	Albite	-7.92	-3.26	4.66	NaAlSi ₃ O ₈
Alunite	-4.31	-0.41	****	Alunite	-4.26	-5.66	-1.40	KAl ₃ (SO ₄) ₂ (OH) ₆
Barite	0.9	1.21	n/a	Anhydrite	-2.50	-6.86	-4.36	CaSO ₄
Chalcedony	0.72	-0.4	0.45	Anorthite	-17.33	8.29	25.62	CaAl ₂ Si ₂ O ₈
Fe(OH) ₃ (a)	****	****	****	Barite	1.19	-8.78	-9.97	BaSO ₄
Gibbsite	-3.23	-0.29	****	Ca-Montmorillonite	-7.96	-0.17	7.78	Ca _{0.165} Al _{2.33} Si _{3.67} O ₁₀ (OH) ₂
Goethite	-4.94	3.1	****	Chalcedony	-0.42	-3.97	-3.55	SiO ₂
Gypsum	-1.96	-2.29	-2.08	Chlorite(14A)	-40.19	28.19	68.38	Mg ₅ Al ₂ Si ₃ O ₁₀ (OH) ₈
Hematite	****	****	****	Chrysotile	-23.12	9.08	32.20	Mg ₃ Si ₂ O ₅ (OH) ₄
Illite	****	****	****	Fe(OH) ₃ (a)	-5.54	12.37	17.91	Fe(OH) ₃
Jarosite	****	****	****	FeS(ppt)	-31.61	-69.18	-37.56	FeS
K-feldspar	****	****	****	Gibbsite	-2.25	5.86	8.11	Al(OH) ₃
K-mica	****	-0.95	****	Goethite	0.35	12.37	12.02	FeOOH
Kaolinite	-3.33	0.3	****	Gypsum	-2.28	-6.86	-4.58	CaSO ₄ ·2H ₂ O
Quartz	1.13	0.01	0.87	H ₂ (g)	-15.60	-15.60	0.00	H ₂
SiO ₂ (a)	-0.13	-1.25	-0.4	H ₂ O(g)	-1.51	-0.00	1.51	H ₂ O
				H ₂ S(g)	-32.16	-73.75	-41.59	H ₂ S
				Halite	-3.61	-2.03	1.58	NaCl
				Hausmannite	-38.86	22.17	61.03	Mn ₃ O ₄
				Hematite	2.71	24.74	22.03	Fe ₂ O ₃
				Illite	-11.18	0.68	11.86	K _{0.6} Mg _{0.25} Al _{2.3} Si _{3.5} O ₁₀ (OH) ₂
				Jarosite-K	-16.00	13.85	29.85	KFe ₃ (SO ₄) ₂ (OH) ₆
				K-feldspar	-8.68	-6.59	2.09	KAlSi ₃ O ₈
				K-mica	-7.56	5.15	12.70	KAl ₃ Si ₃ O ₁₀ (OH) ₂
				Kaolinite	-3.65	3.78	7.43	Al ₂ Si ₂ O ₅ (OH) ₄
				Mackinawite	-30.88	-69.18	-38.30	FeS
				Manganite	-15.35	9.99	25.34	MnOOH
				Melanterite	-4.59	-6.80	-2.21	FeSO ₄ ·7H ₂ O
				O ₂ (g)	-51.92	31.20	83.12	O ₂
				Pyrite	-41.55	-127.33	-85.78	FeS ₂
				Pyrochroite	-13.01	2.19	15.20	Mn(OH) ₂
				Pyrolusite	-23.59	17.79	41.38	MnO ₂
				Quartz	0.01	-3.97	-3.98	SiO ₂
				Sepiolite	-16.34	-0.58	15.76	Mg ₂ Si ₃ O ₇ ·5OH·3H ₂ O
				Sepiolite(d)	-19.24	-0.58	18.66	Mg ₂ Si ₃ O ₇ ·5OH·3H ₂ O
				SiO ₂ (a)	-1.26	-3.97	-2.71	SiO ₂
				Sulfur	-22.44	-58.15	-35.71	S
				Talc	-20.27	1.13	21.40	Mg ₃ Si ₄ O ₁₀ (OH) ₂

Output D1

Mineral phase	P1-D	P1-S	P3-D	Phase	SI	log IAP	log KT	
Al(OH) ₃ (a)	-5.94	-2.99	****	Al(OH) ₃ (a)	-4.01	6.79	10.80	Al(OH) ₃
Albite	****	****	****	Albite	-3.67	0.99	4.66	NaAlSi ₃ O ₈
Alunite	-4.31	-0.41	****	Alunite	-0.45	-1.85	-1.40	KAl ₃ (SO ₄) ₂ (OH) ₆
				Anhydrite	-2.17	-6.53	-4.36	CaSO ₄
				Anorthite	-12.99	12.63	25.62	CaAl ₂ Si ₂ O ₈
				Barite	0.87	-9.10	-9.97	BaSO ₄
				Ca-Montmorillonite	-1.65	6.14	7.78	Ca _{0.165} Al _{2.33} Si _{3.67} O ₁₀ (OH) ₂
				Chalcedony	0.69	-2.86	-3.55	SiO ₂
Barite	0.9	1.21	n/a	Chlorite(14A)	-35.33	33.05	68.38	Mg ₅ Al ₂ Si ₃ O ₁₀ (OH) ₈
Chalcedony	0.72	-0.4	0.45	Chrysotile	-21.10	11.10	32.20	Mg ₃ Si ₂ O ₅ (OH) ₄
				Fe(OH) ₃ (a)	-8.38	9.53	17.91	Fe(OH) ₃
				FeS(ppt)	-32.56	-70.13	-37.56	FeS
Fe(OH) ₃ (a)	****	****	****	Gibbsite	-1.32	6.79	8.11	Al(OH) ₃
				Goethite	-2.48	9.54	12.02	FeOOH
				Gypsum	-1.95	-6.54	-4.58	CaSO ₄ ·2H ₂ O
Gibbsite	-3.23	-0.29	****	H ₂ (g)	-15.20	-15.20	0.00	H ₂
				H ₂ O(g)	-1.51	-0.00	1.51	H ₂ O
Goethite	-4.94	3.1	****	H ₂ S(g)	-30.48	-72.07	-41.59	H ₂ S
				Halite	-3.44	-1.86	1.58	NaCl
Gypsum	-1.96	-2.29	-2.08	Hausmannite	-37.90	23.13	61.03	Mn ₃ O ₄
				Hematite	-2.96	19.07	22.03	Fe ₂ O ₃
				Illite	-4.64	7.22	11.86	K _{0.6} Mg _{0.25} Al _{2.3} Si _{3.5} O ₁₀ (OH) ₂
Hematite	****	****	****	Jarosite-K	-23.49	6.36	29.85	KFe ₃ (SO ₄) ₂ (OH) ₆
				K-feldspar	-3.56	-1.46	2.09	KAlSi ₃ O ₈
Illite	****	****	****	K-mica	-0.57	12.13	12.70	KAl ₃ Si ₃ O ₁₀ (OH) ₂
				Kaolinite	0.44	7.88	7.43	Al ₂ Si ₂ O ₅ (OH) ₄
Jarosite	****	****	****	Mackinawite	-31.83	-70.13	-38.30	FeS
				Manganite	-15.10	10.24	25.34	MnOOH
K-feldspar	****	****	****	Melanterite	-7.15	-9.36	-2.21	FeSO ₄ ·7H ₂ O
				O ₂ (g)	-52.73	30.39	83.12	O ₂
				Pyrite	-41.21	-126.99	-85.78	FeS ₂
K-mica	****	-0.95	****	Pyrochroite	-12.56	2.64	15.20	Mn(OH) ₂
				Pyrolusite	-23.54	17.84	41.38	MnO ₂
Kaolinite	-3.33	0.3	****	Quartz	1.12	-2.86	-3.98	SiO ₂
				Sepiolite	-13.13	2.63	15.76	Mg ₂ Si ₃ O ₇ ·5OH·3H ₂ O
Quartz	1.13	0.01	0.87	Sepiolite(d)	-16.03	2.63	18.66	Mg ₂ Si ₃ O ₇ ·5OH·3H ₂ O
				SiO ₂ (a)	-0.15	-2.86	-2.71	SiO ₂
				Sulfur	-21.16	-56.87	-35.71	S
SiO ₂ (a)	-0.13	-1.25	-0.4	Talc	-16.01	5.39	21.40	Mg ₃ Si ₄ O ₁₀ (OH) ₂

Output D3

Mineral phase	P1-D	P1-S	P3-D	P5-D	P5-S
Al(OH) ₃ (a)	-5.94	-2.99	****	-1.02	-3.79
Albite	****	****	****	0.82 Phase	
Alunite	-4.31	-0.41	****	4.09	Anhydrite
Barite	0.9	1.21	n/a	1.05	Chalcedony
Chalcedony	0.72	-0.4	0.45	0.72	Chrysotile
Fe(OH) ₃ (a)	****	****	****	-2.9	Gypsum
Gibbsite	-3.23	-0.29	****	1.7	H ₂ (g)
Goethite	-4.94	3.1	****	2.94	H ₂ O (g)
Gypsum	-1.96	-2.29	-2.08	-1.8	H ₂ S (g)
Hematite	****	****	****	****	Halite
Illite	****	****	****	4.05	Hausmannite
Jarosite	****	****	****	****	Manganite
K-feldspar	****	****	****	1.13	O ₂ (g)
K-mica	****	-0.95	****	****	Pyrochroite
Kaolinite	-3.33	0.3	****	****	Pyrolusite
Quartz	1.13	0.01	0.87	1.13	Quartz
SiO ₂ (a)	-0.13	-1.25	-0.4	-0.14	-0.25
					Sepiolite
					Sepiolite(d)
					SiO ₂ (a)
					Sulfur
					Talc

SI	log IAP	log KT	
-2.31	-6.67	-4.36	CaSO ₄
0.42	-3.14	-3.55	SiO ₂
-18.28	13.92	32.20	Mg ₃ Si ₂ O ₅ (OH) ₄
-2.10	-6.68	-4.58	CaSO ₄ ·2H ₂ O
-17.60	-17.60	0.00	H ₂
-1.51	-0.00	1.51	H ₂ O
-41.27	-82.85	-41.59	H ₂ S
-3.52	-1.94	1.58	NaCl
-33.69	27.34	61.03	Mn ₃ O ₄
-13.30	12.04	25.34	MnOOH
-47.93	35.19	83.12	O ₂
-11.96	3.24	15.20	Mn(OH) ₂
-20.54	20.84	41.38	MnO ₂
0.85	-3.14	-3.98	SiO ₂
-11.71	4.05	15.76	Mg ₂ Si ₃ O ₇ ·5OH·3H ₂ O
-14.61	4.05	18.66	Mg ₂ Si ₃ O ₇ ·5OH·3H ₂ O
-0.42	-3.14	-2.71	SiO ₂
-29.55	-65.25	-35.71	S
-13.75	7.65	21.40	Mg ₃ Si ₄ O ₁₀ (OH) ₂

Output S5

Mineral phase	P1-D	P1-S	P3-D	P5-D	P5-S	Phase	SI	log IAP	log KT	
Al(OH) ₃ (a)	-5.94	-2.99	****	-1.02	-3.79	Al(OH) ₃ (a)	-1.68	9.12	10.80	Al(OH) ₃
Albite	****	****	****	0.82	-3.55	Albite	-0.78	3.89	4.66	NaAlSi ₃ O ₈
Alunite	-4.31	-0.41	****	4.09	-0.59	Alunite	3.54	2.14	-1.40	KAl ₃ (SO ₄) ₂ (OH) ₆
Barite	0.9	1.21	n/a	1.05	0.97	Anhydrite	-2.09	-6.45	-4.36	CaSO ₄
Chalcedony	0.72	-0.4	0.45	0.72	0.59	Anorthite	-6.57	19.05	25.62	CaAl ₂ Si ₂ O ₈
Fe(OH) ₃ (a)	****	****	****	-2.96	****	Barite	0.96	-9.01	-9.97	BaSO ₄
Gibbsite	-3.23	-0.29	****	1.7	-1.09	Ca-Montmorillonite	3.65	11.44	7.78	Ca _{0.165} Al _{2.33} Si _{3.67} O ₁₀ (OH) ₂
Goethite	-4.94	3.1	****	2.94	-0.38	Chalcedony	0.57	-2.98	-3.55	SiO ₂
Gypsum	-1.96	-2.29	-2.08	-1.87	-1.88	Chlorite(14A)	-21.74	46.64	68.38	Mg ₅ Al ₂ Si ₃ O ₁₀ (OH) ₈
Hematite	****	****	****	****	1.16	Chrysotile	-15.76	16.44	32.20	Mg ₃ Si ₂ O ₅ (OH) ₄
Illite	****	****	****	4.05	-4.27	Fe(OH) ₃ (a)	-3.42	14.49	17.91	Fe(OH) ₃
Jarosite	****	****	****	****	****	FeS(ppt)	-47.55	-85.11	-37.56	FeS
K-feldspar	****	****	****	1.13	-3.45	Gibbsite	1.01	9.12	8.11	Al(OH) ₃
K-mica	****	-0.95	****	****	-0.02	Goethite	2.47	14.49	12.02	FeOOH
Kaolinite	-3.33	0.3	****	****	0.69	Gypsum	-1.87	-6.45	-4.58	CaSO ₄ ·2H ₂ O
Quartz	1.13	0.01	0.87	1.13	1	H ₂ (g)	-19.20	-19.20	0.00	H ₂
SiO ₂ (a)	-0.13	-1.25	-0.4	-0.14	-0.25	H ₂ O(g)	-1.51	-0.00	1.51	H ₂ O
						H ₂ S(g)	-48.42	-90.01	-41.59	H ₂ S
						Halite	-3.57	-1.99	1.58	NaCl
						Hausmannite	-27.55	33.48	61.03	Mn ₃ O ₄
						Hematite	6.95	28.98	22.03	Fe ₂ O ₃
						Illite	1.28	13.14	11.86	K _{0.6} Mg _{0.25} Al _{2.3} Si _{3.5} O ₁₀ (OH) ₂
						Jarosite-K	-11.61	18.24	29.85	KFe ₃ (SO ₄) ₂ (OH) ₆
						K-feldspar	-0.70	1.39	2.09	KAlSi ₃ O ₈
						K-mica	6.93	19.64	12.70	KAl ₃ Si ₃ O ₁₀ (OH) ₂
						Kaolinite	4.85	12.28	7.43	Al ₂ Si ₂ O ₅ (OH) ₄
						Mackinawite	-46.82	-85.11	-38.30	FeS
						Manganite	-10.98	14.36	25.34	MnOOH
						Melanterite	-6.13	-8.34	-2.21	FeSO ₄ ·7H ₂ O
						O ₂ (g)	-44.72	38.40	83.12	O ₂
						Pyrite	-70.14	-155.92	-85.78	FeS ₂
						Pyrochroite	-10.44	4.76	15.20	Mn(OH) ₂
						Pyrolusite	-17.42	23.96	41.38	MnO ₂
						Quartz	1.00	-2.98	-3.98	SiO ₂
						Sepiolite	-9.77	5.99	15.76	Mg ₂ Si ₃ O ₇ ·5OH·3H ₂ O
						Sepiolite(d)	-12.67	5.99	18.66	Mg ₂ Si ₃ O ₇ ·5OH·3H ₂ O
						SiO ₂ (a)	-0.27	-2.98	-2.71	SiO ₂
						Sulfur	-35.10	-70.81	-35.71	S
						Talc	-10.91	10.48	21.40	Mg ₃ Si ₄ O ₁₀ (OH) ₂

Output D5

Mineral phase	P1-D	P1-S	P3-D	P5-D	P5-S	Phase	SI	log IAP	log KT	
Al(OH) ₃ (a)	-5.94	-2.99	****	-1.02	-3.79	Al(OH) ₃ (a)	-1.09	9.71	10.80	Al(OH) ₃
Albite	****	****	****	0.82	-3.55	Albite	0.55	5.22	4.66	NaAlSi ₃ O ₈
Alunite	-4.31	-0.41	****	4.09	-0.59	Alunite	3.91	2.51	-1.40	KAl ₃ (SO ₄) ₂ (OH) ₆
Barite	0.9	1.21	n/a	1.05	0.97	Anhydrite	-2.09	-6.45	-4.36	CaSO ₄
Chalcedony	0.72	-0.4	0.45	0.72	0.59	Anorthite	-4.18	21.44	25.62	CaAl ₂ Si ₂ O ₈
Fe(OH) ₃ (a)	****	****	****	-2.96	****	Barite	0.99	-8.98	-9.97	BaSO ₄
Gibbsite	-3.23	-0.29	****	1.7	-1.09	Ca-Montmorillonite	5.56	13.34	7.78	Ca _{0.165} Al _{2.33} Si _{3.67} O ₁₀ (OH) ₂
Goethite	-4.94	3.1	****	2.94	-0.38	Chalcedony	0.67	-2.88	-3.55	SiO ₂
Gypsum	-1.96	-2.29	-2.08	-1.87	-1.88	Chlorite(14A)	-15.31	53.07	68.38	Mg ₅ Al ₂ Si ₃ O ₁₀ (OH) ₈
Hematite	****	****	****	****	1.16	Chrysotile	-12.59	19.61	32.20	Mg ₃ Si ₂ O ₅ (OH) ₄
Illite	****	****	****	4.05	-4.27	Fe(OH) ₃ (a)	-3.26	14.65	17.91	Fe(OH) ₃
Jarosite	****	****	****	****	****	FeS(ppt)	-57.40	-94.97	-37.56	FeS
K-feldspar	****	****	****	1.13	-3.45	Gibbsite	1.60	9.71	8.11	Al(OH) ₃
K-mica	****	-0.95	****	****	-0.02	Goethite	2.63	14.65	12.02	FeOOH
Kaolinite	-3.33	0.3	****	****	0.69	Gypsum	-1.87	-6.45	-4.58	CaSO ₄ ·2H ₂ O
Quartz	1.13	0.01	0.87	1.13	1	H ₂ (g)	-21.20	-21.20	0.00	H ₂
SiO ₂ (a)	-0.13	-1.25	-0.4	-0.14	-0.25	H ₂ O(g)	-1.51	-0.00	1.51	H ₂ O
						H ₂ S(g)	-57.44	-99.02	-41.59	H ₂ S
						Halite	-3.72	-2.14	1.58	NaCl
						Hausmannite	-22.80	38.23	61.03	Mn ₃ O ₄
						Hematite	7.28	29.31	22.03	Fe ₂ O ₃
						Illite	3.61	15.48	11.86	K _{0.6} Mg _{0.25} Al _{2.3} Si _{3.5} O ₁₀ (OH) ₂
						Jarosite-K	-12.50	17.35	29.85	KFe ₃ (SO ₄) ₂ (OH) ₆
						K-feldspar	0.83	2.92	2.09	KAlSi ₃ O ₈
						K-mica	9.63	22.34	12.70	KAl ₃ Si ₃ O ₁₀ (OH) ₂
						Kaolinite	6.22	13.66	7.43	Al ₂ Si ₂ O ₅ (OH) ₄
						Mackinawite	-56.67	-94.97	-38.30	FeS
						Manganite	-9.07	16.27	25.34	MnOOH
						Melanterite	-7.98	-10.19	-2.21	FeSO ₄ ·7H ₂ O
						O ₂ (g)	-40.72	42.40	83.12	O ₂
						Pyrite	-87.01	-172.79	-85.78	FeS ₂
						Pyrochroite	-9.53	5.67	15.20	Mn(OH) ₂
						Pyrolusite	-14.51	26.87	41.38	MnO ₂
						Quartz	1.10	-2.88	-3.98	SiO ₂
						Sepiolite	-7.49	8.27	15.76	Mg ₂ Si ₃ O ₇ ·5OH·3H ₂ O
						Sepiolite(d)	-10.39	8.27	18.66	Mg ₂ Si ₃ O ₇ ·5OH·3H ₂ O
						SiO ₂ (a)	-0.17	-2.88	-2.71	SiO ₂
						Sulfur	-42.11	-77.82	-35.71	S
						Talc	-7.54	13.86	21.40	Mg ₃ Si ₄ O ₁₀ (OH) ₂

Results

- * Silica SIs remained about the same
- * Seasonal deposition of Fe minerals in some sites

Errors

- * Groundwater composition
- * Mastery of PHREEQC
- * Temperature

Sources

Lee, S. Y. and Gilkes, R.J. (2005), Groundwater geochemistry and composition of hardpans in the southwestern Australian regolith. *Geoderma*, 126, 59-84.

Questions?