

**Major and Trace Elements
in
Southwestern Pennsylvania Soils**

by

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Introduction

Total elemental analysis was one of the earliest chemical analysis methods used to characterize the composition of soil material. With the advent of x-ray analysis emphasis shifted from total analysis to mineralogical analysis and the use of various extracting solutions to determine discrete components of the soil. Examples of this include the use of citrate-bicarbonate-dithionite to extract "free iron oxides" and KCl to extract monomeric aluminum. These shifts occurred in the 1930's and 40's. Although this shift has occurred, significant value still exists in knowing the total elemental analysis of Pennsylvania soil samples. For example, the ratio of free iron oxides to total iron can be used as an index of soil development (Ciolkosz et al., 1993a; Alexander and Holowaychuk, 1983; Alexander, 1985). No concerted effort has been made in the past or is currently underway to inventory these type of data for Pennsylvania soils. Although this is the case, some data are available in obscure places, and it was presented by Ciolkosz et al. (1993b). In the Ciolkosz et al. (1993b) publication, major element data was presented for a group of soils sampled in southwestern Pennsylvania jointly by the USGS and the Penn State Soil Characterization Laboratory. The soils were from Allegheny, Beaver, Butler, Washington, and Westmoreland Counties. In addition to major elements, trace elements were also determined on select horizons of the jointly sampled soil, but these data were not presented in the Ciolkosz et al. (1993b) publication. Background trace element data has become very important information in recent years. Thus, the objective of this presentation is make the unpublished data available. In addition, the original major element data is being reprinted in Table 1 from Ciolkosz et al. (1993b).

Materials and Methods

The soils were sampled horizon by horizon for complete soil characterization analysis, and these data are presented in Cunningham et al. (1977) and Ciolkosz et al. (1976). In addition, the

characterization data are also available in Ciolkosz (2000). Selected horizons of these soils (A, B, and R) were sampled by Peter Briggs of the USGS and sent to the USGS Rapid Rock Analysis Laboratory for total elemental analysis. The method of analysis used by the USGS laboratory is described by Shapiro and Brannock (1962), Shapiro (1967), and Grimes and Marranzino (1968). Three sets of total elemental analysis data are presented. Table 1 gives the major element data that were generated by the joint Penn State-United States Geological Survey (USGS) sampling project. Table 2 gives quantitative data for some selected trace elements, and Table 3 gives semiquantitative trace element data for the sampled soils.

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Table 1. Total elemental composition of selected soil and rock horizons from soils of southwestern Pennsylvania. See Ciolkosz et al. (1976) and Cunningham et al. (1977) for soil descriptions and additional laboratory physical and chemical data for these soils. The physical and chemical data are also given in the Penn State Soil Characterization Database (Ciolkosz and Thurman, 1993). H_2O^- is water loss at 105°C (adsorbed H_2O) and H_2O^+ is water loss above 105°C (crystalline H_2O).

Series Drainage	Soil		Percent														Sum	
	Number	Horizon	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	MnO	CO ₂	S	H ₂ O ⁺		H ₂ O ⁻
<u>Red Calcareous Shales</u>																		
Upshur WD**	02-20-03 (GP7)* 02-20-07 (GP6) 02-20-08 (GP5)	Bt2 C3 2C4	55.0 37.9 37.5	18.6 13.7 13.8	7.2 5.4 2.2	0.88 0.56 0.88	1.60 1.20 1.70	1.10 17.90 19.80	0.18 0.14 0.23	3.2 2.2 1.9	0.87 0.63 0.61	0.12 0.13 0.11	0.09 0.31 0.04	0.25 13.60 15.70	0.00 0.01 0.00	7.0 4.4 4.3	3.8 1.8 1.2	100 100 100
Upshur WD	02-23-03 (GP2) 02-23-08 (GP1)	Bt2 C2	55.5 57.6	19.3 20.0	7.1 6.0	0.40 0.64	1.20 1.30	0.33 0.61	0.14 0.28	2.2 3.1	0.92 1.00	0.17 0.21	0.04 0.05	<0.05 <0.05	0.01 0.01	8.1 6.6	4.6 2.6	100 100
Upshur WD	10-40-03 (GP53) 10-40-10 (GP52)	Bt2 R	56.0 59.2	19.6 19.7	7.3 5.7	0.44 0.36	1.50 1.20	0.59 0.65	0.22 0.17	2.3 2.3	0.87 1.00	0.07 0.11	0.02 0.00	0.01 0.02	0.00 0.00	5.7 5.0	6.2 4.8	101 100
Vandergrift MWD	02-21-04 (GP4) 02-21-09 (GP3)	Bt3 2R	52.4 77.2	20.6 9.7	8.7 3.1	0.56 2.00	1.40 0.76	0.25 0.40	0.20 1.00	2.7 1.1	0.95 0.80	0.07 0.06	0.11 0.11	<0.05 <0.05	0.01 0.01	8.3 3.3	3.8 0.5	100 100
Vandergrift MWD	04-01-04 (GP9) 04-01-11 (GP8)	Bt3 R	50.2 59.0	22.8 21.4	8.6 3.6	0.56 0.60	1.10 1.30	0.36 0.43	0.23 0.24	2.9 3.1	0.93 1.10	0.17 0.06	0.04 0.04	<0.05 <0.05	0.02 0.01	8.9 7.1	3.2 2.1	100 100
<u>Gray and Brown Neutral to Calcareous Shales</u>																		
Westmoreland WD	63-43-03 (GP11) 63-43-08 (GP10)	Bt1 R	64.6 71.6	15.0 12.3	6.8 4.8	0.68 0.92	0.98 0.94	0.28 0.38	0.63 1.20	2.2 1.7	0.97 0.90	0.11 0.10	0.14 0.06	<0.05 <0.05	0.02 0.01	5.6 3.7	2.1 1.2	100 100
Library SWPD	63-44-03 (GP13) 63-44-10 (GP12)	Btg1 5C4g	52.5 57.3	19.2 22.6	9.8 2.4	1.70 0.80	0.97 0.82	0.35 1.50	0.18 0.25	2.7 2.6	0.84 1.10	0.10 0.06	0.06 0.04	<0.05 0.60	0.04 0.02	8.7 7.4	2.8 2.3	100 100
Library SWPD	63-45-03 (GP15) 63-45-09 (GP14)	Bt2 C2	64.9 73.9	14.2 11.5	7.0 3.7	0.40 1.00	0.84 1.10	0.47 0.30	0.50 1.00	2.1 1.7	0.93 0.76	0.08 0.06	0.18 0.07	<0.05 <0.05	0.02 0.01	5.9 4.1	2.4 0.8	100 100

* US Geological Survey Field Number.

** Drainage Class: WD = well drained, MWD = moderate ly well drained, SWPD = somewhat poorly drained.

Table 1. Cont. Total elemental composition of selected soil and rock horizons from soils of southwestern Pennsylvania. See Ciolkosz et al. (1976) and Cunningham et al. (1977) for soil descriptions and additional laboratory physical and chemical data for these soils. The physical and chemical data are also given in the Penn State Soil Characterization Database (Ciolkosz and Thurman, 1993). H_2O^- is water loss at 105°C (adsorbed H_2O) and H_2O^+ is water loss above 105°C (crystalline H_2O).

Series Drainage	Soil														Sum			
	Number	Horizon	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	MnO	CO ₂		S	H ₂ O ⁺	H ₂ O ⁻
<u>Gray and Brown Acid Shales</u>																		
Gilpin WD	65-21-04 (GP20)*	R	75.4	13.6	2.4	0.44	0.63	0.09	0.08	1.6	0.87	0.04	0.06	<0.05	0.02	4.5	0.4	100
Rayne WD	63-46-03 (GP17)	Bt1	70.7	12.0	5.5	0.48	0.74	0.38	0.59	2.0	0.80	0.06	0.14	<0.05	0.03	4.8	1.8	100
	63-46-09 (GP16)	2R	80.9	10.3	1.3	0.52	0.57	0.23	1.40	1.3	0.22	0.11	0.06	<0.05	0.00	2.7	0.4	100
Wharton MWD	65-20-03 (GP19)	Bt2	53.0	19.4	11.7	0.36	0.84	0.15	0.27	2.8	0.95	0.17	0.10	<0.05	0.05	8.1	2.1	100
	65-20-07 (GP18)	R	58.4	22.2	4.2	0.60	1.80	0.31	0.24	3.5	0.15	0.04	0.06	<0.05	0.01	6.8	1.7	100
Cavode SWPD	10-37-05 (GP59)	Btg4	53.1	27.7	3.0	0.44	0.93	0.00	0.40	3.3	1.10	0.04	0.00	0.01	0.00	7.0	3.1	100
	10-37-11 (GP58)	3R	61.0	23.8	1.5	0.64	0.73	0.00	0.31	2.0	1.50	0.04	0.00	0.01	0.00	6.9	2.0	100
Cavode SWPD	10-38-05 (GP57)+	Btg4	58.0	23.5	3.7	0.80	1.30	0.00	0.32	3.3	1.10	0.10	0.00	0.01	0.00	5.8	2.5	100
	10-38-06 (GP57)	Btg5																
	10-38-09 (GP56)	2R	65.4	17.7	4.1	0.88	1.20	0.00	0.25	2.8	1.20	0.06	0.00	0.01	0.00	4.6	1.6	100
Cavode SWPD	10-39-02 (GP55)#	Bt1	64.3	16.8	6.3	0.28	0.69	0.00	0.25	2.0	1.00	0.08	0.00	0.01	0.04	5.0	2.4	99
	10-39-03 (GP55)	Btg1																
	10-39-10 (GP54)	2C	65.5	15.5	6.4	0.24	1.00	0.00	0.24	2.3	1.00	0.17	0.04	0.01	0.02	4.3	3.1	100

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** Drainage Class: WD = well drained, MWD = moderately well drained, SWPD = somewhat poorly drained.

+ Horizons 5 and 6 were combined for analysis.

Horizons 2 and 3 were combined for analysis.

Table 2. Total trace elemental composition of selected soil and rock horizons from soils of southwestern Pennsylvania. See Ciolkosz et al. (1976) and Cunningham et al. (1977) for soil descriptions and additional laboratory physical and chemical data for these soils. The physical and chemical data are also given in the Penn State Soil Characterization Database (Ciolkosz, 2000).

Series Drainage	Soil		Parts Per Million					Percent		
	Number	Horizon	As	Hg	Sb	Zn	Se	F	C	
Upshur WD**	02-20-01 (GP26)*	Ap	10	0.03	< 5	125				
	02-20-03 (GP7)	Bt2	10	0.02	< 5	98				
	02-20-05 (GP25)	C1	8	0.02	< 5	88				
	02-20-07 (GP6)	C3	5	0.04	< 5	71			0.04	
	02-20-08 (GP5)	2C4	15	0.05	< 5	70				
Upshur WD	02-23-01 (GP22)	Ap	15	0.04	< 5	83				
	02-23-03 (GP2)	Bt2	15	0.04	< 5	80				
	02-23-06 (GP21)	Bt5	10	0.04	< 5	100				
	02-23-08 (GP1)	C2	8	0.04	< 5	90			0.19	
Upshur WD	10-40-01 (GP67)	Ap	18	0.04	1.6	124	0.5	0.07		
	10-40-03 (GP53)	Bt2	18	0.03	1.5	98	0.6	0.08		
	10-40-05 (GP68)	BC	15	0.03	1.9	95	0.4	0.08		
	10-40-07 (GP69)	C2	20	0.01	2.1	99	0.2	0.08		
	10-40-10 (GP52)	R	18	0.01	2.1	87	< 0.1	0.07	0.20	
Vandergrift MWD	02-21-01 (GP24)	Ap	10	0.06	< 5	80				
	02-21-04 (GP4)	Bt3	5	0.09	< 5	72				
	02-21-08 (GP23)	2C	8	0.08	< 5	110				
	02-21-09 (GP3)	2R	3	0.02	< 5	80				
Vandergrift MWD	04-01-01 (GP31)	Ap	15	0.05	< 5	84				
	04-01-04 (GP9)	Bt3	30	0.08	< 5	82				
	04-01-07 (GP30)	Bt6g	8	0.04	< 5	110				
	04-01-10 (GP29)	C3	20	0.08	< 5	115				
	04-01-11 (GP8)	R	8	0.03	< 5	155			0.12	

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Table 2. Cont. Total trace elemental composition of selected soil and rock horizons from soils of southwestern Pennsylvania. See Ciolkosz et al. (1976) and Cunningham et al. (1977) for soil descriptions and additional laboratory physical and chemical data for these soils. The physical and chemical data are also given in the Penn State Soil Characterization Database (Ciolkosz, 2000).

Series Drainage	Soil		Parts Per Million							Percent		
	Number	Horizon	As	Hg	Sb	Zn	Se	F	C			
Westmoreland WD**	63-43-01 (GP34)*	Ap	10	0.05	< 5	84						
	63-43-03 (GP11)	Bt1	15	0.03	< 5	84						
	63-43-06 (GP33)	BC	3	0.02	< 5	100						
	63-43-08a (GP32)	R	1	0.02	< 5	77						
	63-43-08b (GP10)	R	2	0.01	< 5	78						
Library SWPD	63-44-01 (GP37)	Ap	30	0.53	< 5	105						
	63-44-03 (GP13)	Btg1	20	0.06	< 5	90						
	63-44-04 & 05(GP36)	Btg2&3	10	0.08	< 5	48						
	63-44-08 (GP35)	3C2g	25	0.13	< 5	58			0.30			
	63-44-10 (GP12)	5C4g	5	0.04	< 5	80						
Library SWPD	63-45-01 (GP41)	Ap	15	0.05	< 5	110						
	63-45-03 (GP15)	Bt2	20	0.05	< 5	72						
	63-45-05 (GP40)	Bt4g	20	0.05	< 5	86						
	63-45-07 (GP39)	BCg	20	0.05	< 5	125						
	63-45-09 (GP14)	C2	3	0.02	< 5	124						
<u>Gray and Brown Acid Shales</u>												
Gilpin WD	65-21-01 (GP51)	Ap	8	0.05	< 5	135						
	65-21-04 (GP20)	R	3	0.02	< 5	70						
Rayne WD	63-46-01 (GP45)	Ap	10	0.04	< 5	78						
	63-46-03 (GP17)	Bt1	10	0.04	< 5	70						
	63-46-05 (GP44)	Bt3	10	0.05	< 5	83						
	63-46-06 (GP43)	BC	5	0.04	< 5	55						
	63-46-08 (GP42)	2C2	3	0.02	< 5	72						
	63-46-09 (GP16)	2R	1	0.02	< 5	52						

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Series Drainage	Soil		Parts Per Million							Percent		
	Number	Horizon	As	Hg	Sb	Zn	Se	F	C			
Wharton MWD**	65-20-01 (GP49)*	Ap	15	0.06	< 5	150						
	65-20-03 (GP19)	Bt2	15	0.06	< 5	95						
	65-20-06 (GP48)	BC	10	0.05	< 5	94						
	65-20-07 (GP18)	R	8	0.03	< 5	132						
Cavode SWPD	10-37-01 (GP60)	Ap	12	0.04	0.9	87	0.9	0.04				
	10-37-05 (GP59)	Btg4	8	0.04	0.8	58	1.6	0.06				
	10-37-09 (GP61)	3C3	12	0.20	1.4	50	1.5	0.09				
	10-37-11 (GP58)	3R	8	0.04	0.8	62	0.8	0.05		< 0.10		
Cavode SWPD	10-38-01 (GP62)	Ap	12	0.04	1.0	115	0.8	0.05				
	10-38-05 (GP57)+	Btg4	12	0.03	1.0	105	0.6	0.08				
	10-38-06 (GP57)	Btg5	5	0.02	0.9	149	0.7	0.08				
	10-38-08 (GP63)	2C	3	0.01	0.5	109	0.2	0.06		0.20		
Cavode SWPD	10-39-01 (GP64)	Ap	20	0.04	1.2	98	0.9	0.05				
	10-39-02 (GP55)#	Bt1	30	0.03	1.4	73	0.8	0.06				
	10-39-03 (GP55)	Btg1										
	10-39-05 (GP65)	Btg4g	12	0.04	1.2	90	1.1	0.08				
	10-39-07 (GP66)	2Btg	12	0.04	1.1	120	0.4	0.11				
	10-39-10 (GP54)	2C	5	0.03	1.3	130	0.5	0.05		0.10		

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+ Horizons 5 and 6 were combined for analysis.

Horizons 2 and 3 were combined for analysis.

Table 3. Semiquantitative 6-step spectrographic total analysis data (Grimes and Marranzino, 1968) of selected soil and rock horizons from soils of southwestern Pennsylvania. See Ciolkosz et al. (1976) and Cunningham et al. (1977) for soil descriptions and additional laboratory physical and chemical data for these soils. The physical and chemical data are also given in the Penn State Soil Characterization Database (Ciolkosz, 2000).

Series Drainage	Soil																				
	Number	Horizon	Fe	Mg	Ca	Ti	Si	Al	Na	K	P	Mn	Ag	As	Au	B	Ba	Be	Bi	Cd	
Detection Limit***			0.001	0.002	0.002	0.0002	0.002	0.001	0.05	0.7	0.2	0.5	1000	20	20	1.5	1	10	10	20	
<u>Red Calcareous Shales</u>																					
Upshur WD**	02-20-01 (GP26)* 02-20-03 (GP7) 02-20-05 (GP25) 02-20-07 (GP6) 02-20-08 (GP5)	Ap Bt2 C1 C3 2C4	3 3 3 2 0.7	0.5 0.5 0.5 0.3 0.5	0.2 0.5 2 7 7	0.2 0.2 0.2 0.15 0.1	G 10 G 7 7	7 7 7 3 3	0.3 0.15 0.3 0.3 0.3	3 3 3 3 3	N N N N N	300 200 200 700 1000	N N N N N	N N N N N	N L 30 L L	30 200 200 150 150	1.5 1.5 1.5 1.5 N	N N N N N	N N N N N	N N N N N	
Upshur WD	02-23-01 (GP22) 02-23-03 (GP2) 02-23-06 (GP21) 02-23-08 (GP1)	Ap Bt2 Bt5 C2	3 3 3 3	0.5 0.3 0.5 0.5	0.15 0.1 0.15 0.2	0.3 0.2 0.3 0.3	G G G G	5 7 7 7	0.3 0.15 0.15 0.3	1.5 2 3 3	N N N N	1000 30 70 70	N N N N	N N N N	30 L 20 30	200 150 500 300	1.5 1.5 2 3	N N N N	N N N N	N N N N	
Upshur WD	10-40-01 (GP67) 10-40-03 (GP53) 10-40-05 (GP68) 10-40-07 (GP69) 10-40-10 (GP52)	Ap Bt2 BC C2 R	5 7 5 5 5	1 1 2 1 1	0.7 5 0.7 0.7 5	0.5 0.5 0.5 0.5 0.7	G G G G G	G G G G G	0.3 0.3 0.2 0.15 0.2	3 5 5 5 5	N N N N N	1000 300 150 150 100	N N N N N	N N N N N	N N N N N	50 50 30 50 50	500 500 500 500 500	2 2 3 3 3	N N N N N	N N N N N	
Vandergrift MWD	02-21-01 (GP24) 02-21-04 (GP4) 02-21-08 (GP23) 02-21-09 (GP3)	Ap Bt3 2C 2R	3 3 2 2	0.3 0.5 0.5 0.3	0.07 0.07 0.07 0.15	0.3 0.2 0.3 0.2	G G G G	7 7 7 3	0.3 0.3 0.3 0.7	3 3 3 0.7	N N N N	1500 50 150 300	N N N N	N N N N	30 20 30 L	300 150 300 150	1.5 1.5 2 N	N N N N	N N N N	N N N N	
Vandergrift MWD	04-01-01 (GP31) 04-01-04 (GP9) 04-01-07 (GP30) 04-01-10 (GP29) 04-01-11 (GP8)	Ap Bt3 Bt6g C3 R	2 5 1.5 1.5 1.5	0.2 0.3 0.3 0.3 0.5	0.1 0.1 0.15 0.2 0.15	0.2 0.3 0.3 0.2 0.3	G G G G G	5 7 7 7 7	0.3 -- 0.3 0.15 0.3	1.5 3 3 3 3	N N N N N	1000 70 100 30 70	N N N N N	N N N N N	30 L 30 30 30	300 300 300 200 300	1.5 1.5 3 3 1.5	N N N N N	N N N N N	N N N N N	

* US Geological Survey Field Number.

** Drainage Class: WD = well drained, MWD = moderately well drained, SWPD = somewhat poorly drained.

*** G = Greater than 10%; N = not detected at limit of detection; L = detected but below limit of determination; --not looked for.

Table 3. Cont. Semiquantitative 6-step spectrographic total analysis data (Grimes and Marranzino, 1968) of selected soil and rock horizons from soils of southwestern Pennsylvania. See Ciolkosz et al. (1976) and Cunningham et al. (1977) for soil descriptions and additional laboratory physical and chemical data for these soils. The physical and chemical data are also given in the Penn State Soil Characterization Database (Ciolkosz, 2000).

Series Drainage	Soil Number	Horizon	Parts Per Million																	
			Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Pd	Pt	Sb	Sc	Sn	Sr	Te	U	V	W
Detection Limit***			3	1	1	30	3	10	5	10	1	30	150	5	10	5	2000	500	7	100
<u>Red Calcareous Shales</u>																				
Upspur WD**	02-20-01 (GP26)*	Ap	15	70	30	L	N	L	30	30	N	N	N	15	N	100	N	N	70	N
	02-20-03 (GP7)	Bt2	7	70	30	L	N	L	30	15	N	N	N	10	N	70	N	N	70	N
	02-20-05 (GP25)	C1	10	70	150	L	N	L	30	20	N	N	N	15	N	150	N	N	70	N
	02-20-07 (GP6)	C3	7	70	30	L	N	L	15	15	N	N	N	7	N	150	N	N	70	N
	02-20-08 (GP5)	2C4	7	70	30	L	N	L	15	20	N	N	N	10	N	150	N	N	70	N
Upspur WD	02-23-01 (GP22)	Ap	15	70	30	L	N	L	15	30	N	N	N	7	N	70	N	N	70	N
	02-23-03 (GP2)	Bt2	7	70	30	L	N	L	20	20	N	N	N	15	N	30	N	N	70	N
	02-23-06 (GP21)	Bt5	10	70	70	L	N	L	30	20	N	N	N	15	N	70	N	N	70	N
	02-23-08 (GP1)	C2	7	70	70	L	N	L	30	15	N	N	N	15	N	150	N	N	70	N
Upspur WD	10-40-01 (GP67)	Ap	20	100	50	70	N	10	50	15	N	N	N	15	N	150	N	N	150	N
	10-40-03 (GP53)	Bt2	20	150	50	70	N	10	70	15	N	N	N	20	N	150	N	N	200	N
	10-40-05 (GP68)	BC	15	150	30	50	N	10	50	20	N	N	N	20	N	100	N	N	150	N
	10-40-07 (GP69)	C2	15	150	100	50	N	L	50	30	N	N	N	20	N	100	N	N	150	N
	10-40-10 (GP52)	R	15	150	50	70	N	10	70	20	N	N	N	20	N	100	N	N	150	N
Vandergrift MWD	02-21-01 (GP24)	Ap	20	70	30	50	N	10	20	30	N	N	N	15	N	70	N	N	70	N
	02-21-04 (GP4)	Bt3	7	70	50	L	N	L	30	15	N	N	N	15	N	70	N	N	70	N
	02-21-08 (GP23)	2C	20	70	30	L	N	L	30	20	N	N	N	15	N	70	N	N	100	N
	02-21-09 (GP3)	2R	7	30	15	L	N	L	10	15	N	N	N	7	N	70	N	N	30	N
Vandergrift MWD	04-01-01 (GP31)	Ap	15	50	30	L	N	L	15	70	N	N	N	7	N	70	N	N	70	N
	04-01-04 (GP9)	Bt3	7	70	150	70	N	L	30	50	N	N	N	15	N	300	N	N	150	N
	04-01-07 (GP30)	Bt6g	15	100	100	50	N	L	50	70	N	N	N	15	N	100	N	N	150	N
	04-01-10 (GP29)	C3	7	150	300	70	7	L	20	150	N	N	N	15	N	150	N	N	300	N
	04-01-11 (GP8)	R	15	70	50	L	N	L	30	20	N	N	N	15	N	100	N	N	150	N

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Series Drainage	Soil																			
	Number	Horizon	Y	Zn	Zr	Ce	Ga	Ge	Hf	In	Li	Re	Ta	Th	Tl	Yb	Pr	Nd	Sm	Eu
Detection Limit***																				
<u>Red Calcareous Shales</u>																				
Upshur WD**	02-20-01 (GP26)*	Ap	15	N	70	L	30	N	N	N	L	N	N	N	N	2	N	L	N	N
	02-20-03 (GP7)	Bt2	15	N	70	N	30	N	N	N	L	N	N	N	N	2	N	L	N	N
	02-20-05 (GP25)	C1	15	N	70	L	30	N	N	N	L	N	N	N	N	1.5	N	L	N	N
	02-20-07 (GP6)	C3	15	N	50	N	15	N	N	N	L	N	N	N	N	1.5	--	N	N	N
	02-20-08 (GP5)	2C4	15	N	30	N	15	N	N	N	L	N	N	N	N	1.5	--	N	N	N
Upshur WD	02-23-01 (GP22)	Ap	15	N	70	L	15	N	N	N	L	N	N	N	N	3	N	L	N	N
	02-23-03 (GP2)	Bt2	10	N	70	L	15	N	N	N	L	N	N	N	N	1.5	N	N	N	N
	02-23-06 (GP21)	Bt5	15	N	70	L	30	N	N	N	L	N	N	N	N	2	N	L	N	N
	02-23-08 (GP1)	C2	15	N	70	L	30	N	N	N	L	N	N	N	N	3	N	L	N	N
Upshur WD	10-40-01 (GP67)	Ap	30	N	150	N	20	N	N	N	L	N	N	N	N	5	N	L	N	N
	10-40-03 (GP53)	Bt2	20	N	150	L	20	N	N	N	L	N	N	N	N	3	N	L	N	N
	10-40-05 (GP68)	BC	20	N	100	N	20	N	N	N	L	N	N	N	N	3	N	N	N	N
	10-40-07 (GP69)	C2	30	N	100	N	20	N	N	N	L	N	N	N	N	3	N	N	N	N
	10-40-10 (GP52)	R	30	N	150	L	30	N	N	N	N	N	N	N	N	3	N	70	N	N
Vandergrift MWD	02-21-01 (GP24)	Ap	30	N	150	L	20	N	N	N	L	N	N	N	N	3	N	L	N	N
	02-21-04 (GP4)	Bt3	10	N	70	L	30	N	N	N	100	N	N	N	N	1.5	N	L	N	N
	02-21-08 (GP23)	2C	15	N	70	L	30	N	N	N	150	N	N	N	N	2	N	L	N	N
	02-21-09 (GP3)	2R	15	N	300	L	10	N	N	N	L	N	N	N	N	3	N	L	N	N
Vandergrift MWD	04-01-01 (GP31)	Ap	20	N	100	L	15	N	N	N	L	N	N	N	N	3	N	L	N	N
	04-01-04 (GP9)	Bt3	15	N	700	L	30	N	N	N	--	N	N	N	N	2	N	70	N	N
	04-01-07 (GP30)	Bt6g	30	N	70	L	30	N	N	N	150	N	N	N	N	3	N	70	N	N
	04-01-10 (GP29)	C3	15	N	70	L	50	N	N	N	L	N	N	N	N	3	N	70	N	N
	04-01-11 (GP8)	R	20	N	100	L	30	N	N	N	L	N	N	N	N	3	N	L	N	N

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Series Drainage	Soil													Parts Per Million									
	Number	Horizon	Fe	Mg	Ca	Ti	Si	Al	Na	K	P	Mn	Ag	As	Au	B	Ba	Be	Bi	Cd			
Detection Limit***																							
<u>Gray and Brown Neutral to Calcareous Shales</u>																							
Westmoreland WD**	63-43-01 (GP34)*	Ap	1.5	0.2	0.15	0.2	G	3	0.7	1.5	N	1500	N	N	N	30	500	1.5	N	N			
	63-43-03 (GP11)	Bt1	3	0.3	0.07	0.3	G	5	0.7	2	N	300	N	N	N	30	300	1.5	N	N			
	63-43-06 (GP33)	BC	3	0.5	0.07	0.3	G	7	0.7	3	N	300	N	N	N	30	300	1.5	N	N			
	63-43-08a (GP32)	R	2	0.5	0.07	0.3	G	5	0.7	1.5	N	150	N	N	N	30	300	1.5	N	N			
	63-43-08b (GP10)	R	2	0.3	0.1	0.3	G	5	0.7	1.5	N	150	N	N	N	30	300	1.5	N	N			
	63-44-01 (GP37)	Ap	3	0.2	0.2	0.2	G	5	0.5	2	N	500	N	N	N	30	300	1.5	N	N			
Library SWPD	63-44-03 (GP13)	Btg1	5	0.2	0.07	0.2	G	7	0.3	3	N	100	N	N	N	30	300	1.5	N	N			
	63-44-04&05 (GP36)	Btg2&3	1.5	0.5	0.15	0.2	G	7	0.5	3	N	30	N	N	N	30	300	1.5	N	N			
	63-44-08 (GP35)	3C2g	2	0.5	0.3	0.2	G	7	0.3	3	N	150	N	N	N	30	300	2	N	N			
	63-44-10 (GP12)	5C4g	1	0.2	0.3	0.2	G	7	0.3	3	N	50	N	N	N	30	200	1.5	N	N			
	63-45-01 (GP41)	Ap	2	0.2	0.3	0.3	G	5	0.7	1.5	N	700	N	N	N	30	300	1.5	N	N			
Library SWPD	63-45-03 (GP15)	Bt2	3	0.2	0.15	0.3	G	5	0.5	1.5	N	500	N	N	N	30	300	1.5	N	N			
	63-45-05 (GP40)	Bt4g	3	0.3	0.2	0.3	G	7	0.5	2	N	700	N	N	N	30	300	1.5	N	N			
	63-45-07 (GP39)	BCg	2	0.5	0.3	0.2	G	5	0.5	2	N	500	N	N	N	30	200	1.5	N	N			
	63-45-09 (GP14)	C2	2	0.3	0.15	0.3	G	3	0.7	1.5	N	150	N	N	N	30	200	1.5	N	N			
	65-21-01 (GP51)	Ap	2	0.2	0.1	0.2	G	3	0.15	1.5	N	700	N	N	N	L	300	1.5	N	N			
	65-21-04 (GP20)	R	0.7	0.15	0.01	0.15	G	3	0.1	1.5	N	100	N	N	N	L	150	L	N	N			
Rayne WD	63-46-01 (GP45)	Ap	1.5	0.5	0.15	0.3	G	3	0.7	1.5	N	1000	N	N	N	20	300	1.5	N	N			
	63-46-03 (GP17)	Bt1	3	0.2	0.1	0.2	G	5	0.7	1.5	N	300	N	N	N	L	300	1.5	N	N			
	63-46-05 (GP44)	Bt3	3	0.2	0.07	0.15	G	3	0.7	1.5	N	500	N	N	N	L	150	1.5	N	N			
	63-46-06 (GP43)	BC	2	0.2	0.07	0.15	G	3	0.7	1.5	N	300	N	N	N	30	200	1.5	N	N			
	63-46-08 (GP42)	2C2	3	0.3	0.07	0.3	G	5	0.7	1.5	N	500	N	N	N	30	200	1.5	N	N			
	63-46-09 (GP16)	2R	0.7	0.2	0.1	0.3	G	2	0.5	0.7	N	150	N	N	N	30	150	L	N	N			

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Series Drainage	Soil																				
	Number	Horizon	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Pd	Pt	Sb	Sc	Sn	Sr	Te	U	V	W	
Detection Limit***			3	1	1	30	3	10	5	10	1	30	150	5	10	5	2000	500	7	100	
<u>Gray and Brown Neutral to Calcareous Shales</u>																					
Westmoreland WD**	63-43-01 (GP34)* 63-43-03 (GP11) 63-43-06 (GP33) 63-43-08a (GP32) 63-43-08b (GP10)	Ap Bt1 BC R R	10 15 15 10 10	30 50 70 30 30	15 30 30 15 20	50 L 50 L 50	N N N N N	10 L L L L	15 20 30 20 15	20 20 20 15 15	N N N N N	N N N N N	N N 15 7 7	7 7 15 7 7	N 70 70 50 70	N N N N N	N N N N N	N N N N N	50 70 70 70 70	N N N N N	
Library SWPD	63-44-01 (GP37) 63-44-03 (GP13) 63-44-04&05 (GP36) 63-44-08 (GP35) 63-44-10 (GP12)	Ap Bt1 Bt2&3 3C2g 5C4g	10 5 5 7 7	70 70 70 70 70	30 50 30 30 70	L L L L L	L N N L N	L L L L L	20 15 15 30 20	70 30 20 30 30	N N N N N	N N N N N	N N N N N	7 15 10 15 15	50 70 150 100 150	N N N N N	N N N N N	N N N N N	70 70 100 100 100	N N N N N	
Library SWPD	63-45-01 (GP41) 63-45-03 (GP15) 63-45-05 (GP40) 63-45-07 (GP39) 63-45-09 (GP14)	Ap Bt2 Bt4g BCg C2	10 15 15 15 15	50 70 70 50 30	30 30 30 30 20	70 L L L L	3 N N L N	10 L 10 L L	15 20 30 30 30	30 30 20 20 15	N N N N N	N N N N N	N N N N N	10 10 10 10 7	100 100 150 70 30	N N N N N	N N N N N	N N N N N	70 70 70 70 30	N N N N N	
<u>Gray and Brown Acid Shales</u>																					
Gilpin WD	65-21-01 (GP51) 65-21-04 (GP20)	Ap R	10 7	50 30	30 15	L L	N N	L L	15 10	20 15	N N	N N	N N	7 7	N 30	N N	N N	N N	70 30	N N	
Rayne WD	63-46-01 (GP45) 63-46-03 (GP17) 63-46-05 (GP44) 63-46-06 (GP43) 63-46-08 (GP42) 63-46-09 (GP16)	Ap Bt1 Bt3 BC 2C2 2R	7 7 7 7 7 5	30 30 30 30 30 15	15 15 15 10 15 5	L L N N L L	N N N N N N	L L L L 10 10	15 15 20 15 20 7	15 15 15 15 15 15	N N N N N N	N N N N N N	N N N N N N	7 7 7 7 10 5	70 70 30 30 50 30	N N N N N N	N N N N N N	30 70 70 50 70 30	N N N N N N		

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Series Drainage	Soil Number	Horizon	Parts Per Million																					
			Y	Zn	Zr	Ce	Ga	Ge	Hf	In	Li	Re	Ta	Th	Ti	Yb	Pr	Nd	Sm	Eu				
Detection Limit***			10	200	10	1.5	5	10	10	100	10	10	50	30	200	200	200	50	1	100	70	100	100	
<u>Shales</u>																								
<u>Gray and Brown Neutral to Calcareous</u>																								
Westmoreland WD**	63-43-01 (GP34)*	Ap	20	N	150	L	15	N	N	N	N	L	N	N	N	N	N	N	3	N	L	N	N	N
	63-43-03 (GP11)	Bt1	15	N	150	L	15	N	N	N	N	N	N	N	N	N	N	N	3	N	L	N	N	N
	63-43-06 (GP33)	BC	30	N	150	L	20	N	N	N	N	L	N	N	N	N	N	N	3	N	70	N	N	N
	63-43-08a (GP32)	R	20	N	200	L	15	N	N	N	N	L	N	N	N	N	N	N	3	N	L	N	N	N
	63-43-08b (GP10)	R	30	N	300	L	15	N	N	N	N	N	N	N	N	N	N	N	5	N	70	N	N	N
	63-44-01 (GP37)	Ap	15	N	70	L	30	N	N	N	N	L	N	N	N	N	N	N	2	N	L	N	N	N
Library SWPD	63-44-03 (GP13)	Btg1	10	N	70	L	30	N	N	N	L	N	N	N	N	N	N	N	1.5	N	L	N	N	N
	63-44-04&05 (GP36)	Btg2&3	15	N	70	L	50	N	N	N	150	N	N	N	N	N	N	N	1.5	N	L	N	N	N
	63-44-08 (GP35)	3C2g	15	N	70	L	30	N	N	N	150	N	N	N	N	N	N	N	2	N	L	N	N	N
	63-44-10 (GP12)	5C4g	10	N	70	L	30	N	N	N	L	N	N	N	N	N	N	N	1.5	N	L	N	N	N
	63-45-01 (GP41)	Ap	20	N	150	L	15	N	N	N	L	N	N	N	N	N	N	N	3	N	L	N	N	N
Library SWPD	63-45-03 (GP15)	Bt2	15	N	150	L	15	N	N	N	L	N	N	N	N	N	N	N	3	N	L	N	N	N
	63-45-05 (GP40)	Bt4g	15	N	100	L	20	N	N	N	L	N	N	N	N	N	N	N	3	N	L	N	N	N
	63-45-07 (GP39)	BCg	15	N	100	L	30	N	N	N	L	N	N	N	N	N	N	N	2	N	L	N	N	N
	63-45-09 (GP14)	C2	15	N	30	L	15	N	N	N	L	N	N	N	N	N	N	N	3	N	L	N	N	N
	65-21-01 (GP51)	Ap	15	N	150	L	15	N	N	N	L	N	N	N	N	N	N	N	2	N	L	N	N	N
Gilpin WD	65-21-04 (GP20)	R	L	N	150	L	15	N	N	N	L	N	N	N	N	N	N	N	1.5	N	N	N	N	N
	63-46-01 (GP45)	Ap	20	N	150	N	10	N	N	N	L	N	N	N	N	N	N	N	3	N	N	N	N	N
Rayne WD	63-46-03 (GP17)	Bt1	10	N	150	L	15	N	N	N	L	N	N	N	N	N	N	N	2	N	L	N	N	N
	63-46-05 (GP44)	Bt3	10	N	100	L	15	N	N	N	L	N	N	N	N	N	N	N	1.5	N	N	N	N	N
	63-46-06 (GP43)	BC	L	N	70	L	15	N	N	N	L	N	N	N	N	N	N	N	1.5	N	N	N	N	N
	63-46-08 (GP42)	2C2	20	N	150	L	15	N	N	N	L	N	N	N	N	N	N	N	2	N	L	N	N	N
	63-46-09 (GP16)	2R	10	N	150	L	7	N	N	N	L	N	N	N	N	N	N	N	1.5	N	L	N	N	N

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Series Drainage	Soil											Parts Per Million								
	Number	Horizon	Fe	Mg	Ca	Ti	Si	Al	Na	K	P	Mn	Ag	As	Au	B	Ba	Be	Bi	Cd
Detection Limit***			0.001	0.002	0.002	0.0002	0.002	0.001	0.05	0.7	0.2	0.5	1000	20	20	1.5	1	10	20	
<u>Gray and Brown Acid Shales</u>																				
Wharton MWD**	65-20-01 (GP49)	Ap	3	0.2	0.1	0.3	G	7	0.15	1.5	N	1000	N	N	L	300	1.5	N	N	
	65-20-03 (GP19)	Bt2	3	0.2	0.05	0.15	G	7	0.2	3	N	150	N	N	L	200	1.5	N	N	
	65-20-06 (GP48)	BC	2	0.3	0.07	0.2	G	7	0.3	3	N	200	N	N	20	300	1.5	N	N	
	65-20-07 (GP18)	R	1.5	0.5	0.07	0.3	G	7	0.3	3	N	150	N	N	30	300	3	N	N	
Cavode SWPD	10-37-01 (GP60)	Ap	3	0.3	0.3	0.7	G	7	0.5	2	N	1000	N	N	50	700	1.5	N	N	
	10-37-05 (GP59)	Btg4	3	0.7	0.04	0.5	G	G	0.5	5	N	30	N	N	50	1000	3	N	N	
	10-37-9 (GP61)	3C3	1.5	1	0.05	0.5	G	G	0.5	7	N	20	N	N	70	1000	3	N	N	
	10-37-11 (GP58)	3R	1.5	0.5	0.07	0.7	G	G	0.3	5	N	20	N	N	50	700	2	N	N	
Cavode SWPD	10-38-01 (GP62)	Ap	3	0.5	0.05	0.5	G	10	0.3	2	N	2000	N	N	50	700	1.5	N	N	
	10-38-05 (GP57)+	Btg4	3	1	0.02	0.5	G	G	0.5	7	N	70	N	N	50	700	3	N	N	
	10-38-06 (GP57)	Btg5																		
	10-38-08 (GP63)	2C	5	1	0.02	0.5	G	G	0.3	5	N	150	N	N	70	700	2	N	N	
	10-38-09 (GP56)	2R	5	1	0.05	0.7	G	G	0.3	5	N	300	N	N	50	700	2	N	N	
Cavode SWPD	10-39-01 (GP64)	Ap	5	0.5	0.15	0.5	G	10	0.3	3	N	1000	N	N	50	700	2	N	N	
	10-39-02 (GP55)#	Bt1	5	0.5	0.05	0.5	G	10	0.3	3	N	150	N	N	50	500	2	N	N	
	10-39-03 (GP55)	Btg1																		
	10-39-05 (GP65)	Bt4g	5	1	0.05	0.5	G	G	0.2	5	N	70	N	N	70	700	3	N	N	
	10-39-07 (GP66)	2Bt6g	5	1	0.15	0.5	G	G	0.2	5	N	1000	N	N	70	700	3	N	N	
	10-39-10 (GGP54)	2C	5	0.7	0.05	0.5	G	G	0.3	5	N	700	N	N	50	700	3	N	N	

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+ Horizons 5 and 6 were combined for analysis.

Horizons 2 and 3 were combined for analysis.

Table 3. Cont. Semiquantitative 6-step spectrographic total analysis data (Grimes and Marranzino, 1968) of selected soil and rock horizons from soils of southwestern Pennsylvania. See Ciolkosz et al. (1976) and Cunningham et al. (1977) for soil descriptions and additional laboratory physical and chemical data for these soils. The physical and chemical data are also given in the Penn State Soil Characterization Database (Ciolkosz, 2000).

Series Drainage	Soil																				
	Number	Horizon	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Pd	Pt	Sb	Sc	Sn	Sr	Te	U	V	W	
Detection Limit***			3	1	1	30	3	10	5	10	1	30	150	5	10	5	2000	500	7	100	
<u>Gray and Brown Acid Shales</u>																					
Wharton MWD**	65-20-01 (GP49)	Ap	15	50	30	L	N	L	15	30	N	N	N	10	N	150	N	N	70	N	
	65-20-03 (GP19)	Bt2	7	70	20	L	N	L	30	20	N	N	N	15	N	100	N	N	150	N	
	65-20-06 (GP48)	BC	7	70	30	L	N	L	15	30	N	N	N	15	N	150	N	N	70	N	
	65-20-07 (GP18)	R	15	70	20	L	N	L	30	20	N	N	N	15	N	100	N	N	150	N	
Cavode SWPD	10-37-01 (GP60)	Ap	20	70	20	70	N	15	20	30	N	N	N	10	N	150	N	N	100	N	
	10-37-05 (GP59)	Btg4	5	200	30	70	N	10	20	20	N	N	N	20	N	500	N	N	300	N	
	10-37-9 (GP61)	3C3	5	200	15	70	N	10	20	50	N	N	N	20	N	500	N	N	300	N	
	10-37-11 (GP58)	3R	7	150	20	50	N	15	30	15	N	N	N	20	N	150	N	N	200	N	
Cavode SWPD	10-38-01 (GP62)	Ap	30	70	20	70	N	10	30	30	N	N	N	15	N	100	N	N	100	N	
	10-38-05 (GP57)+	Btg4	10	150	30	70	N	10	50	20	N	N	N	20	N	200	N	N	200	N	
	10-38-06 (GP57)	Btg5																			
	10-38-08 (GP63)	2C	15	150	30	70	N	15	50	15	N	N	N	20	N	150	N	N	150	N	
	10-38-09 (GP56)	2R	15	150	30	70	N	10	50	20	N	N	N	20	N	150	N	N	150	N	
Cavode SWPD	10-39-01 (GP64)	Ap	20	100	20	50	N	10	20	30	N	N	N	15	N	150	N	N	150	N	
	10-39-02 (GP55)#	Bt1	10	70	30	50	N	10	20	30	N	N	N	15	N	150	N	N	150	N	
	10-39-03 (GP55)	Btg1																			
	10-39-05 (GP65)	Bt4g	7	150	30	70	N	10	30	30	N	N	N	30	N	200	N	N	300	N	
	10-39-07 (GP66)	2Bt6g	15	100	50	70	N	10	50	20	N	N	N	20	N	150	N	N	150	N	
	10-39-10 (GGP54)	2C	20	100	50	70	N	10	50	15	N	N	N	15	N	150	N	N	150	N	

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Series Drainage	Soil																				
	Number	Horizon	Y	Zn	Zr	Ce	Ga	Ge	Hf	In	Li	Re	Ta	Th	Tl	Yb	Pr	Nd	Sm	Eu	
Detection Limit***	10		10	200	10	1.5	5	10	100	10	50	30	200	200	50	1	100	70	100	100	
<u>Gray and Brown Acid Shales</u>																					
Wharton MWD**	65-20-01 (GP49)	Ap	15	N	100	L	20	N	N	N	L	N	N	N	N	3	N	L	N	N	
	65-20-03 (GP19)	Bt2	10	N	70	L	30	N	N	N	L	N	N	N	N	1.5	N	L	N	N	
	65-20-06 (GP48)	BC	15	N	70	L	30	N	N	N	L	N	N	N	N	2	N	L	N	N	
	65-20-07 (GP18)	R	15	N	100	L	30	N	N	N	L	N	N	N	N	2	N	L	N	N	
Cavode SWPD	10-37-01 (GP60)	Ap	30	N	500	L	15	N	N	N	N	N	N	N	N	3	N	L	N	N	
	10-37-05 (GP59)	Btg4	30	N	100	L	50	N	N	N	200	N	N	N	N	3	N	70	N	N	
	10-37-9 (GP61)	3C3	20	N	150	L	70	N	N	N	300	N	N	N	N	3	N	L	N	N	
	10-37-11 (GP58)	3R	30	N	300	N	50	N	N	N	500	N	N	N	N	5	N	N	N	N	
Cavode SWPD	10-38-01 (GP62)	Ap	30	N	300	L	15	N	N	N	L	N	N	N	N	3	N	70	N	N	
	10-38-05 (GP57)+	Btg4	30	N	150	L	30	N	N	N	100	N	N	N	N	3	N	100	N	N	
	10-38-06 (GP57)	Btg5																			
	10-38-08 (GP63)	2C	50	N	300	L	30	N	N	N	100	N	N	N	N	3	N	70	N	N	
	10-38-09 (GP56)	2R	50	N	300	L	30	N	N	N	L	N	N	N	N	7	N	70	N	N	
Cavode SWPD	10-39-01 (GP64)	Ap	30	N	200	L	20	N	N	N	L	N	N	N	N	3	N	N	N	N	
	10-39-02 (GP55) #	Bt1	20	N	200	N	20	N	N	N	L	N	N	N	N	3	N	N	N	N	
	10-39-03 (GP55)	Btg1																			
	10-39-05 (GP65)	Bt4g	30	N	150	L	30	N	N	N	100	N	N	N	N	3	N	70	N	N	
	10-39-07 (GP66)	2Bt6g	50	N	100	L	30	N	N	N	L	N	N	N	N	3	N	70	N	N	
	10-39-10 (GGP54)	2C	30	N	200	N	20	N	N	N	L	N	N	N	N	5	N	L	N	N	

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