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STRONTIUM, STRONTIUM-90, AND CALCIUM ANALYSES OF CLINCH AND TENNESSEE RIVER CLAMS

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ABSTRACT

Analyses of clam shells for Sr, Sr^{90}, and Ca are reported in order to provide data on individual clams of 16 species for other workers. The data include 208 Sr, 80 Sr^{90}, and 35 Ca analyses. Information on age of the clam and shell weight are also included because the Sr concentration in some shells is affected by age and growth rate. A detailed description of sample treatment and preparation is also included. An interpretation of the results of these analyses has been published.

Introduction

The purpose of this report is to provide data on the Sr, Sr^{90}, and Ca content of individual fresh-water clam shells as well as details on the method of sample preparation. Interpretations of the results of these analyses have been published in the open literature (1,2). In these papers average Sr concentrations were given for the different species of clams from several collecting sites. In analyzing the data on Sr concentrations it became apparent there were not only species differences but also differences within a species which could be attributed to age, growth rate, or collection site. Because of these differences, it was impossible to compare adequately the current series of analyses with previously published data. The publication of these individual chemical analyses together with data on the age and shell weight will provide a source for future workers in other regions who may wish to make comparisons. Studies of Sr concentrations in clams from contrasting chemical environments will contribute to the understanding of the biogeochemistry of Sr in fresh-water environments. The only other known published analyses of Sr in fresh-water clams from North America are those of Odum (3) (41 analyses) and Thompson and Chow (4) (2 analyses). In both of these papers the Sr concentration is expressed as the Sr to Ca atom ratio.

Materials and Methods

Clams were collected from seven different sites on the Tennessee River system during the summer and fall of 1960. The Clinch River and Grassy Creek specimens were obtained by searching shallow areas and picking up individuals when they were seen. The Tennessee River specimens

were procured from commercial clam fishery operators. These clams occur in water 15 to 30 feet deep and are brought to the surface by use of a crow-foot brail. A number of specimens of Elliptio crassidens and E. dilatatus were obtained from the University of Michigan Museum of Zoology through the courtesy of Drs. H. W. van der Schalie and J. B. Burch, and are marked UMMZ as the collection site. Actually all of these latter specimens were collected in the Clinch and Tennessee Rivers prior to the construction of Tennessee Valley Authority dams. The collection sites on the Clinch and Tennessee Rivers are indicated by Clinch River mile (CRM) and Tennessee River mile (TRM) numbers. River miles are measured upstream from the mouth of the river. The Clinch River joins the Tennessee River at TRM 567.6. Grassy Creek is a tributary of the Clinch River and the confluence is at CRM 14.5 The Grassy Creek specimens were obtained from the embayment which is flooded at the maximum pool levels of Watts Bar Reservoir.

Clams were identified by comparison with a reference collection prepared at the University of Michigan Museum of Zoology. Ages of specimens were determined by the annual ring method (5). This method depends on the formation of growth checks (annual rings) of crowded layers during the winter period of slow growth. Adverse environmental conditions at other seasons may produce false annuli. It is usually possible to detect these false annual rings in clams less than 10 years old but as individuals become older, the annuli become more crowded and it is increasingly difficult to determine the age of clams accurately. For example, the growth rings of Proptera alata shells are difficult to interpret accurately; consequently, ages of these clams are not included.

The right one-half of the shell was analyzed and the weights reported are for this portion of the shell. Shells were dried in an oven at 103°C for at least 24 hours, weighed, and then ashed in a muffle furnace at 500°C for two hours to destroy organic matter. The ash weight of the shell is reported here as is the percent organic matter determined by loss on ignition. After ashing, the shells were placed in a beaker, covered with distilled water and dissolved by the gradual addition of concentrated HCl. In dissolving the shells it was assumed the entire shell weight was due to $CaCO_3$, therefore, stoichiometric amounts of HCl were added plus 1 to 2% excess to insure an adequate quantity was present to dissolve the shell. The beakers were covered with a watch glass and kept on the low heat of a hot plate during dissolution. The solution was filtered through a Whatman No. 40 paper and the residue was washed at least three times with 0.1 N HCl. A spectrographic analysis of the filter papers showed inconsequential amounts of Sr and Ca on the filters.

Some of the preliminary analyses were done on shells which were dried at 103°C, dissolved by the addition of concentrated HCl and then the organic matter was destroyed by the addition of $HClO_4$. These samples may be identified by the absence of data on the percent of organic matter (Table 1). The Sr, Sr^{90}, and Ca contents of the wet-ashed samples were corrected to an ash-weight basis by using a correction factor calculated from the average per cent loss on ignition for all other samples. The average loss on ignition was 3.83% and the correction factor was 1.04.

Calcium and Sr were determined by flame spectrophotometric methods (6,7). The Sr analyses were verified by spectrographic determinations on sample aliquots. A radiochemical separation was used to obtain Sr^{90} and

Table 1. Age, ash weight, Ca, Sr and Sr^{90} concentrations and percent organic matter in Clinch and Tennessee River clams analyzed.

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (µg/g)	Sr^{90} (µµc/g)	Organic Matter (%)
		Actinonaias carinata gibba--TRM 47				
VII:25:60	10	59.33*		173		3.96
"	8	38.74		181		3.87
"	10	55.88*		180		4.27
"	9	47.88*		172		3.94
"	11	84.40*		195		3.56
"	9	47.62*		185		4.05
"	14	85.52*	404	214		3.91
		Amblema costata--CRM 47				
VII:25:60	8	52.22		184		3.70
"	12	70.59		185		3.70
		Amblema costata--TRM 425				
X:2:60	10	135.00*		201	6.198	3.72
"	11	105.50		184	6.369	3.80
"	12	116.60*		220		3.49
		Anodonta corpulenta--Grassy Creek				
XII:9:60	3	18.92		383	31.23	4.08
XII:20:60	2	12.01		294	32.41	4.12
XII:20:60	2	21.80		263	35.71	3.97
XII:20:60	5	19.40		354, 361	30.28	3.82

Table 1, Continued

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (μg/g)	Sr^{90} (μμc/g)	Organic Matter (%)
		Anodonta corpulenta--CRM 4.7-14.5				
VII:27:60	13	83.16		518	134.4	
XII:5:60	7	68.82		238	82.48	4.17
XI:9:60	4	26.36	396	387	151.8	3.78
"	2	7.129		232	38.16	3.39
XII:5:60	11	122.9		441	107.0	3.90
XII:6:60	4	36.05	411	426	37.69	3.62
"	7	86.89		434	142.0	3.84
		Cyclonaias tuberculata--CRM 47				
VII:25:60	13	38.79*		210	0.0929	
"	14	38.77*		217	0.7063	
"	12	38.76				
"	16	87.02*				
		Cyclonaias tuberculata--TRM 521				
V:25:60	14	46.86		255	4.613	
"	16	71.08*		283	3.397	
"	11	39.88		227	5.874	
"	13	50.97*		240	5.090	
"	13	51.41		255	7.009	
"	14	46.03		237		
"	15	57.09*		238		
"	15	51.29		225		
"	11	36.62		233	4.074	
"	9	42.60		233	3.637	

Table 1, Continued

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (µg/g)	Sr^{90} (µµc/g)	Organic Matter (%)
			Cyclonaias tuberculata--TRM 425			
X:2:60	14	70.80		218	7.865	
"	18	85.15		220	4.676	
"	14	76.05		202	5.401	
"	15	73.93		175	4.869	4.12
"	15	61.28				
"	8	44.13				
			Cyclonaias tuberculata--TRM 100			
XI:21:60	12	44.94		210, 211	3.969	3.52
"	16	50.20		204		3.62
"	8	35.22		220	2.804	3.61
"	10	37.52		223	2.401	3.67
"	11	34.36		187	3.356	3.71
			Dromas dromus--CRM 66			
VII:24:60	10	26.26*		205, 198		3.11
			Dromas dromus--CRM 47			
VII:25:60	9	44.77		177		3.26
"	10	36.38		189		3.50
			Elliptio crassidens--CRM 47			
VII:25:60	32	103.7		266		
"	26	93.65*		262		

Table 1, Continued

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (μg/g)	Sr^{90} (μμc/g)	Organic Matter (%)
VII:25:60	30	123.7*		272		
"	21	87.93*		277		
"	28	100.7*		274		
"	18	123.2*	390	244		4.15
"	17	105.4*		256		4.26
"	17	125.3*		247		4.19
"	13	86.76*		232		4.23
"	14	93.13*		281, 277		4.39
		Elliptio crassidens--TRM 521				
V:25:60	15	64.50		195, 204	12.71	
"	14	64.09		219	7.171	
"	12	52.56		254	8.054	
"	11	53.43		197	11.97	
"	10	57.77		208, 213	8.032	
"	10	47.00		204, 213		
"	11	43.23		200, 204		
"	9	43.42		216		
"		54.91		218, 227		
"		56.46		212, 222		

Table 1, Continued

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (µg/g)	Sr^{90} (µµc/g)	Organic Matter (%)
V:25:60	6	36.26	387	212	14.51	4.12
"	5	37.74		201	11.08	3.92
"	5	27.51		207	18.33	4.19
"	5	29.18		201	10.87	4.39
"	3	20.77		202	9.369	4.14
"		70.16	397			
"		84.07	403			
"		64.93	400			
"		61.39	401			
"		96.16	404			
		Elliptio crassidens--TRM 425				
X:2:60	11	93.34		215	7.806	
"	15	102.5		219	3.604	4.10
"	6	44.66		201	9.842	4.16
"	15	111.8		180	6.045	
"	14	109.7		175	8.212	
"	10	96.82		186	6.329	
"	10	107.2		199	7.144	
		Elliptio crassidens--TRM 100				
XI:21:60	11	77.68	408	253	1.507	4.13
"	14	76.83		259	1.759	3.74
"	12	64.23		242	3.226	4.00

Table 1, Continued

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (µg/g)	Sr^{90} (µµc/g)	Organic Matter (%)
XI:21:60	11	70.25		176, 175	3.463	4.04
"	4	20.34	405	211	9.833	4.10
		Elliptio crassidens--UMMZ				
IX:1925	14	78.15		188		4.40
"	9	39.72	399	164		4.54
Before 1934	12	49.30		170		4.36
"	7	29.98		167		4.12
"	2	8.225		158		4.11
1939	22	83.91		226		4.41
		Elliptio dilatatus--CRM 66				
VII:24:60	6	8.291		215		3.64
"	7	6.230*		228		3.67
		Elliptio dilatatus--CRM 47				
VII:25:60	8	11.14*	395	198	- 0.0324	3.90
"	8	12.78*		202	0.8176	3.85
"	9	10.11*		225		4.14
"	9	11.89*		197, 200		3.68
"	9	8.921*		231		3.60
"	11	11.51*		217		3.59
"	10	15.59*		212		3.36
"	9	13.83*		185		3.88

Table 1, Continued

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (µg/g)	Sr^{90} (µµc/g)	Organic Matter (%)
VII:25:60	6	12.80*		181		3.84
"	7	10.26*		213		4.02
		Elliptio dilatatus--TRM 425				
X:2:60	16	55.83	403	218	4.164	3.40
		Elliptio dilatatus--UMMZ				
	5	6.513	392	213		3.97
	5	7.267*		206		3.90
	15	14.38		213		3.71
	12	16.62		184		3.95
	15	16.67		186		3.72
	20	18.95*		196		3.42
	12	8.899*		167		3.75
	12	18.88*				4.26
		Fusconaia subrotunda--CRM 66				
VII:24:60	6	12.54*		201		4.13
"	8	17.66*		209		3.52
"	8	14.35*		202		4.15
"	7	13.26*		187, 181		4.10
"	7	13.33*		196		3.72
"	6	14.37*		185		3.66
		Fusconaia subrotunda--CRM 47				
VII:25:60	10	24.14		173		3.91

Table 1, Continued

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (μg/g)	Sr^{90} (μμc/g)	Organic Matter (%)
VII:25:60	10	19.63*		200		4.19
"	12	38.84		195		3.68
"	12	40.22*		183		3.73
"	14	54.26*		226, 215		3.21
"	11	26.69*		185		3.78
"	12	29.88		189		3.85
"	11	34.57*	400	189		3.87
"	12	31.32		184		3.66
"	12	31.91		189		3.72
"	8	24.32		177		3.82
		Lampsilis ovata--CRM 66				
VII:24:60	9	36.21*		211	0.3484	3.77
"	8	29.01*		228		3.90
"	9	50.20*		232		3.78
"	5	26.95*		252	0.4411	3.61
"	6	44.69*		232		3.75
"	9	51.60*		205		3.61
		Lampsilis ovata--CRM 47				
VII:25:60	13	86.25*		251		3.48
"	13	73.26*		249		3.73
"	6	62.03*		211		3.81
"	3	35.09*	408	192	0.7910	3.66

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (μg/g)	Sr^{90} (μμc/g)	Organic Matter (%)
VII:25:60	5	84.84*		250, 250 236		3.67
"	5	69.20*		196	- 0.0063	3.71
XI:8:60	12	96.55*		259, 260 254		3.44
		Ligumia recta latissima--CRM 47				
VII:25:60	12	87.83*		196		
"	9	60.10		178		3.99
"	8	43.52		172		3.99
"	10	63.62	406	181		3.92
"	12	77.50		181		3.92
"	10	62.92*		185		3.81
		Ligumia recta latissima--CRM 425				
X:2:60	4	39.55		191		4.06
		Megalonaias gigantea--TRM 425				
X:2:60	18	169.8		194, 194, 188, 186		4.32
"	22	247.6	409	203, 197,		4.22
"	19	188.2		188, 185, 183		4.28

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (µg/g)	Sr^{90} (µµc/g)	Organic Matter (%)
		Plagiola lineolata--TRM 425				
X:2:60	14	114.0		207		4.13
"	10	54.05		199		4.46
"	11	81.04		193		3.94
		Pleurobema cordatum--CRM 47				
VII:25:60	14	46.01		187		3.46
"	9	32.89		187		3.85
"	14	53.34		190		3.90
"	23	83.14*		212		3.59
"	14	36.95	403	219	0.3707	
"	20	52.18		213		3.50
"	6	24.85		198	- 0.0004	3.94
"	12	38.26		189		3.90
"	11	34.76		180		3.99
"	12	41.87		235		3.91
		Pleurobema cordatum--TRM 425				
X:2:60	19	103.6		237		3.58
"	23	132.7		245		3.55
"	24	117.3*		258		3.44
"	16	75.04		205		3.82
"	20	112.0		229, 230, 237		
"	20	97.28	394	238		

Table 1, Continued

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (μg/g)	Sr^{90} (μμc/g)	Organic Matter (%)
X:2:60	9	88.75		217	7.635	3.66
"	18	107.8		221		
"	14	77.31		220	1.212	3.61
"	17	84.75		281		3.79
"	10	65.06		256, 256		3.46
		Proptera alata--Grassy Creek				
XII:19:60		75.95		247		4.39
XII:20:60		117.9		227		3.72
"		194.5		193		3.62
"		131.2		215		4.25
		Proptera alata--TRM 521				
V:25:60		35.17	404	248		4.19
		Proptera alata--TRM 425				
X:2:60		23.79		190		4.34
		Quadrula metanevra--CRM 47				
VII:25:60	11	29.33		162		3.71
		Quadrula metanevra--TRM 425				
X:2:60	7	39.82		161		3.43
"	7	41.24		160		3.37
"	4	21.66		164		3.43

Table 1, Continued

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (μg/g)	Sr^{90} (μμc/g)	Organic Matter (%)
			Quadrula pustulosa--CRM 16.8			
IX:21:60	8	20.25	419, 406	161		4.14
"	11	17.04	406, 397	150, 148	12.69	4.19
"	10	15.53	382	144, 148	10.79	4.28
"	7	14.60	392	158	24.19	3.03
"	9	20.20	407	158		3.96
"	7	16.25	390	148, 147	17.52	3.98
"	8	17.30	391	158	10.73	3.26
"	8	18.84	403	160		4.21
"	9	23.42	399	167, 159, 168		4.00
"	8	23.14				4.00
			Quadrula pustulosa--CRM 47			
VII:25:60	9	16.78		192	0.9662	
"	7	11.09		180	1.462	
"	11	26.92				
			Quadrula pustulosa--CRM 521			
VII:25:60	9	41.88		277	4.410	
"	17	30.51		211	6.257	
"	13	39.96				

Collection Date	Age (years)	Ash Wt. (g)	Ca (mg/g)	Sr (μg/g)	Sr^{90} (μμc/g)	Organic Matter (%)
		Quadrula pustulosa--TRM 425				
X:2:60	14	36.07		217	4.595	
"	12	43.55		189	2.793	
"	13	57.10		202	5.522	
"	15	32.29				
		Quadrula pustulosa--TRM 100				
XI:21:60	11	34.23	412	214	2.210	3.69
"	9	39.14		193, 190		3.84
"	9	28.25		197	2.169	3.61
"	14	36.83		197		3.33
"	11	32.38		212, 202	3.005	3.80
"	10	43.09		208		3.42
"	8	25.59		198	1.972	3.66
"	7	26.00	396	178, 188	2.079	3.60

counting was done in a low-background counter (8). The counting time for the Sr^{90} determinations was 20 minutes which was sufficient for samples collected downstream from White Oak Creek. Samples collected upstream from White Oak Creek contained Sr^{90} produced by weapons fallout and three negative values are reported. These negative numbers were included in the mean Sr^{90} level for the upstream collecting site.

Results of the analyses are listed by species and by collection site (Table 1). Replicate chemical analyses on sample aliquots were completed in some cases and are shown by the inclusion of two or more analytical values for one sample. Some samples were lost in processing, hence data are present for age and weight with no corresponding chemical analyses. Concentrated H_3PO_4 was inadvertently added to a number of samples and this interfered with the subsequent Sr determination. These Sr values, one-half to two-thirds those of similar samples, were omitted.

Clam shells frequently are eroded at the umbo resulting in a loss of shell material. It is difficult to estimate accurately the amount of shell material lost through this process. Since subsequent analyses showed there is a nonhomogeneous distribution of Sr in clam shells, the shells having erosion at the umbo are indicated by an asterisk after the shell weight (Table 1). Erosion was particularly severe with Lampsilis ovata shells from CRM 47 and 66 and Elliptio crassidens shells from CRM 47.

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