~~NRC PDR~~

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 26 1979

MEMORANDUM FOR: Jay B. Durst, Assistant Director
for Safeguards and Systems
Performance Research
Division of Safeguards, Fuel Cycle
and Environmental Research

FROM: Donald E. Solberg
Systems Performance Branch
Division of Safeguards, Fuel Cycle
and Environmental Research

SUBJECT: FACILITY DECOMMISSIONING RESEARCH REVIEW GROUP MEETING NOTES

On June 8, 1979, members of the Decommissioning Research Review Group met to discuss research program status and results, formal proposals for future research and additional research needs. The meeting agenda is presented in Enclosure 1 and the list of attendees is presented in Enclosure 2.

Long-Lived Activation Products Research (Fin No. B2296)

John Evans (PNL) presented the plans and results of this research program. The visual materials distributed at the meeting is presented in Enclosure 3. Pages 3-1 through 3-4 provide background information and are self explanatory. Available samples of unirradiated vessel, vessel internals and concrete are presented on page 3-5. The WNP 1/4 samples of concrete, aggregate, rebar and structural steel were obtained from the WPPSS construction at Hanford. Breakdown of the aggregate species is presented on page 3-6. A concrete core from the SMUD Rancho Seco Plant in Sacramento has been obtained. Six stainless steel samples have been obtained from a nuclear material supplier for reactor vessel internals. A single vessel steel sample has been obtained from BCL, i.e., SA 302B. GE sample materials exist at BCL and at the time of the meeting all necessary approvals had been obtained to receive sample material, although, the samples had not actually been received at PNL.

Identified irradiated samples are presented on page 3-7. The Point Beach #1 samples have been received. Negotiations on other identified samples are in progress.

The samples identified on pages 3-5 and 3-7 represent only those identified this far by PNL; the search for additional relevant materials will continue. It was stressed at the meeting that:

- o concrete samples should be obtained which cover a wide geographical distribution
- o irradiated concrete specimens have not been found but the search should continue since they would be most useful to the program,

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- o vessel materials from suppliers other than Westinghouse should be obtained.

Analysis results of concrete and aggregate samples are presented in the tables on pages 3-13 through 3-16. On pages 3-13 and 3-14 are presented results for the Rancho Seco concrete sample, three concrete sample pours (SP) from WPPSS (used for compression tests), six aggregate samples and finally data for the earth's crustal abundance for comparison. On pages 3-15 and 3-16 are presented the analysis results for several rock classifications obtained from the WPPSS aggregate. Data from both tables are shown normalized to the earth's crustal abundance in the figures on pages 3-17 through 3-20. Of the aggregate materials analyzed, quartz appears to have the lowest concentration of materials which will potentially lead to long-lived activation products and granite appears to be the next best choice. The ratio of the abundance of elements analyzed for these two rock types to the average abundance of all aggregate types analyzed is presented on page 3-21. The lines connecting data points are only present as an aid to visualizing the results.

A list of action items developed as a result of discussions is presented in Enclosure 4.

In response to the question of how the PNL program compares with the British program being performed by Woollam (CEGB), Evans responded that the following improvements are available in the PNL project:

- o Activation calculations using a spectrum of neutrons energies will be used
- o The radiochemistry will be of a higher quality.
- o The program will provide information on geographical effects on concrete composition and vendor effects on steel composition.

For the record, it should also be noted that the U.S. study is based on PWRs and BWRs whereas the British study was based on gas cooled reactors. There is no clear evidence that U.S. construction materials have the same proportions of minor and trace elements as the British materials.

Dave Robertson (PNL) gave a brief summary of the planned research project "Characterization of Radionuclide Contamination Throughout Light Water Reactor Power Stations," (Fin No. B2299)*. The only NRC staff comment on the proposed research was that shorter-lived radioisotopes should be studied as well as long-lived radioisotopes. These are necessary to evaluate decommissioning dose rates and for the evaluation of appropriate methods to reduce those dose rates. Radioisotopes with half-lives as short as 90 days should be evaluated.

*This project was officially authorized on July 5, 1979.

Lyle Perrigo presented his plan for proposed research to evaluate decontamination as a precursor to decommissioning. This presentation closely followed the draft 189a which was enclosed with the notice for this meeting. NRC staff recommendations are presented in Enclosure 5. Mr. Perrigo will rewrite and resubmit the 189a.

Because there was insufficient time for the NRC staff to discuss the final agenda item "Additional Decommissioning Needs," this item was deferred to a later date.

Donald E. Solberg

Donald E. Solberg
Systems Performance Branch
Division of Safeguards, Fuel Cycle and Environmental Research

Enclosures:
1. Agenda
2. Attendees
3. Presentation Material (B2296)
4. Action Items (B2296)
5. Action Items (Perrigo)

cc and Attendees:
R. M. Bernero, SD
D. Crutchfield, NRR
L. Barrett, NRR/DOR
A. Abriss, NMSS/FCLB
A. T. Clar, NMSS
L. Rubenstein, NRR
C. Bartlett, RES

ENCLOSURE 1

Agenda
Nuclear Plant Decommissioning
Research Review Group

June 8, 1979	Phillips Building, Room P-114
8:30 a.m.	Opening Remarks, D. Solberg
8:40	Presentation of Long-Lived Activation Project Results and Plans, J. Evans, PNL
10:15	Coffee Break
10:30	Continuation, J. Evans
12:00	Lunch
1:15 p.m.	Discussion of Plans to Characterize LWR contamination, NRC staff, L. Rancitelli, PNL
2:00	Discussion of comments on PNL Plan for Project "Decontamination as a Precursor to Decommissioning", NRC staff
2:45	Coffee Break
3:00	Discussion of Additional Decommissioning Research Needs and Approaches to Initiating Responsive Projects

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ATTENDANCE LIST
Decommissioning Research Review Group Meeting
June 8, 1979

Donald Solberg, RES

Don Calkins, SD

Carl Feldman, SD

Lou Rancilillo, PNL

Leo Faust, PNL

Lyle Perrigo, PNL

John Evans, PNL

Dave Robertson, PNL

Dick Bangart, DSE

Richard Emch, DOR

Pete Erickson, DOR

Tim Johnson, NMSS

ENCLOSURE 3

Presentation Material (B2296)

LONG LIVED ACTIVATION PRODUCTS IN REACTOR MATERIALS

Initiated February 1979

MAJOR TASKS

CHEMICAL ANALYSIS OF REACTOR MATERIALS

- CALCULATION OF EXPECTED RADIONUCLIDE ABUNDANCES
  - NEUTRON CAPTURE REACTION
  - FAST NEUTRON REACTIONS
- RADIOCHEMICAL ASSAY ON SELECTED ACTIVATED SAMPLES

TARGET ELEMENTS

	NEUTRON CAPTURE			OTHER		
T 1/2 (YEARS)	5.3 - 100	100 - 1000	>1000	5.3 - 100	100 - 1000	>1000
	Co	Ag	Cl, S	Li	K	Al
	Cd	ir, Os	Ca	Rb	Ca	Fe
	Sn		Ni	Sr		Sm
	Eu, Sm		Se	Ba		Pb
	Hf		Zr			Bi
	U		Nb			B
			Mo			N
			Pd			Ba
			Cs			
			Ho, Dy			
			Re, W			
			Th			
			U			

MATERIALS TO BE CONSIDERED

• REACTOR INTERNALS	STAINLESS STEEL 304 AND 316
• PRESSURE VESSEL	LOW ALLOY STEEL
• BIOSHIELD CONCRETE	CEMENT COARSE AGGREGATE FINE AGGREGATE REBAR STRUCTURAL STEEL

UNIRRADIATED SAMPLES

TYPE	SOURCE
• CONCRETE AGGREGATE REBAR STRUCTURAL STEEL	WNP 1/4 RANCHO SECO
• VESSEL STEEL	BCL - GE WESTINGHOUSE - EPRI SA 302 B (1)
• STAINLESS STEEL	NUCLEAR SUPPLIER 304 (3) 316 (3)

WPPSS CONCRETE

CEMENT

WATER

SAND

AGGREGATE - COLUMBIA RIVER BASALT
YAKIMA BASALT
GRANITE
GRANODIORITE
QUARTZ
QUARTZITE
GREENSTONE
MONZANITE

REBAR

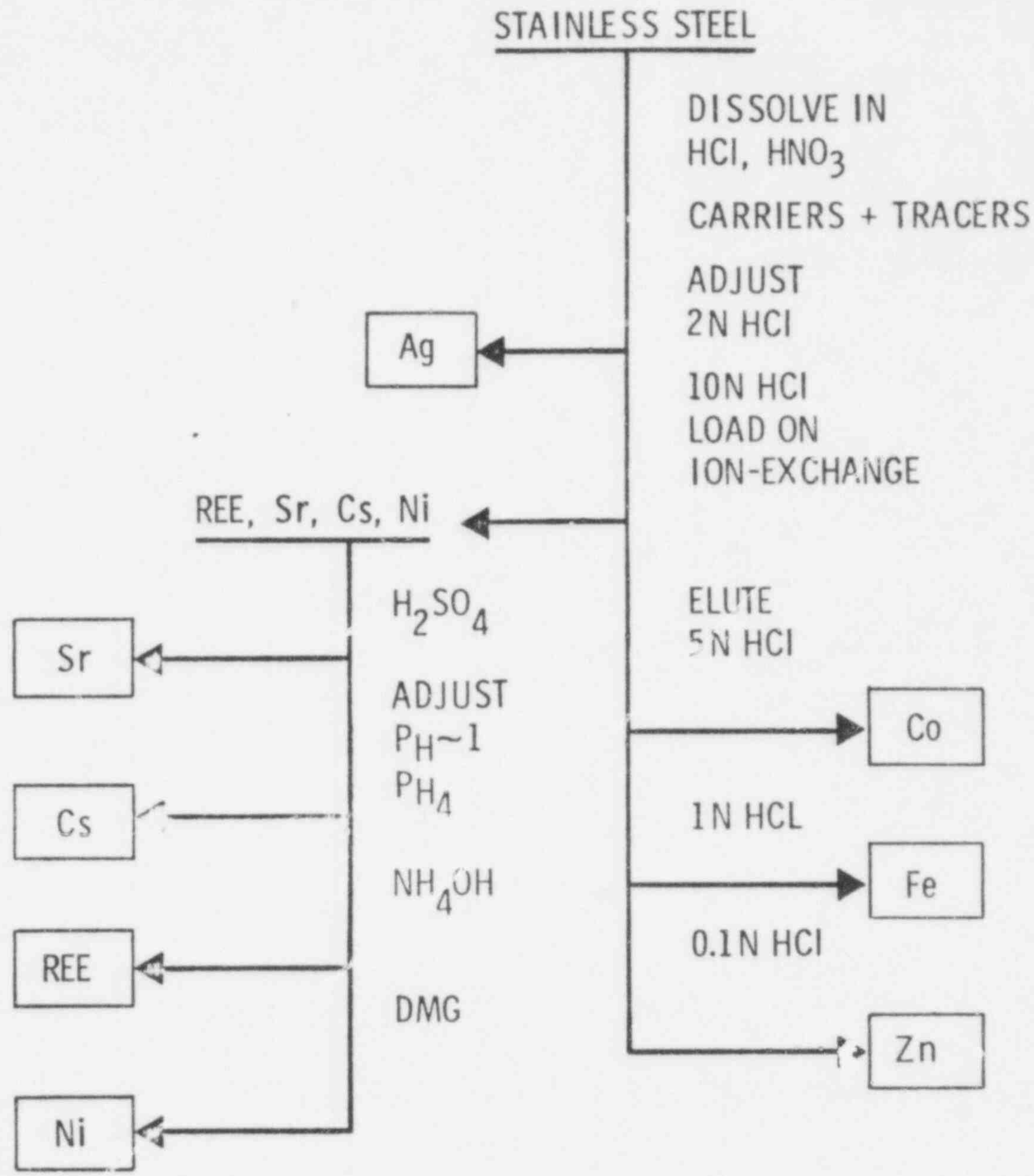
STRUCTURAL STEEL

8303215

ACTIVATED SAMPLES FOR RADIOCHEMICAL ANALYSIS

• POINT BEACH #1 - 1971 FUEL SUPPORT STRUCTURE	STAINLESS STEEL 304 ZIRCALOY 4 INCONEL 718
• BCL - GE TENSILE STRENGTH SAMPLES	VESSEL STEEL 2 - 4 SAMPLES
• WESTINGHOUSE COUPON HANGERS	STAINLESS STEEL
• WESTINGHOUSE - EPRI	VESSEL STEEL 8 - 10 SAMPLES UP TO 30 EFPY

RADIOCHEMICAL FLOW SCHEME
(Ag, Co, Cs, Ni, REE, Sr, Zn)



RADIONUCLIDE PROPERTIES*

ELEMENT	ISOTOPE	T1/2	SELECTED ENERGY (keV)
Ag	^{108m}Ag	130 y	434, 614
	^{110m}Ag	255 d	658, 764
Co	^{57}Co	270 d	122, 136
	^{60}Co	5.2 y	1173, 1332
Cs	^{134}Cs	2.1 y	605, 796
	^{135}Cs	3.0×10^6 y	BETA
	^{137}Cs	30 y	662
Ni	^{59}Ni	8×10^4 y	X-RAY
	^{63}Ni	92 y	BETA
REE	^{145}Pm	17.7 y	72
	^{151}Sm	87 y	22
	^{152}Eu	12.7 y	122, 344
	^{154}Eu	16 y	724, 876
	^{155}Eu	1.8 y	87, 105
	^{158}Tb	1200 y	80, 182
	^{166m}Ho	1200 y	280, 412
Sr	^{90}Sr	28 y	BETA
Zn	^{65}Zn	245 d	1115

* COUNTING: BETA, NaI (Tl), INTRINSIC AND Ge (Li) SYSTEMS

RADIOCHEMICAL FLOW SCHEME
(^{3}H, C, Cl, Mn, Mo, Nb, Zr, Hf, Pu)

INDIVIDUAL READIOCHEMICAL SEPARATIONS

- ^{3}H
- ^{14}C
- ^{36}Cl
- ^{239}Pu

GROUP SEPARATIONS

- Zr AND Hf
- Mn, Mo AND Nb

RADIONUCLIDE PROPERTIES*

ELEMENT	ISOTOPE	$T_{1/2}$	SELECTED ENERGY (keV)
T	^{3}H	12.6 y	BETA
C	^{14}C	5730 y	BETA
Cl	^{36}Cl	3.1×10^{5} y	X-RAY
Pu	^{239}Pu	2.4×10^{4} y	X-RAY, ALPHA
Zr	^{93}Zr	1.5×10^{6} y	BETA, X-RAY
Hf	^{178m}Hf	31 y	424
Mn	^{54}Mn	312 d	835
Mo	^{93}Mo	3500 y	X-RAY
Nb	^{93m}Nb	13.6 y	X-RAY
	^{94}Nb	2.0×10^{4} y	702, 871

*COUNTING: BETA, ALPHA, NaI (Tl), INTRINSIC AND Ge (Li) SYSTEMS

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T	^{3}H	12.6 y	BETA
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*COUNTING: BETA, ALPHA, NaI (Tl), INTRINSIC AND Ge (Li) SYSTEMS

POOR ORIGINAL

Concrete and Aggregate (PPM unless otherwise noted)

SAMPLE	L.	B	N	% Na	% Al	% S	Cl	% K	% Ca	% Fe	Co	Ni	Zn	As	Se	Br	Rb	Sr	Zr	Nb	Mo	Pb	Ag	Cd	Sn	Cs	Ba	Sm	Eu	Tb
Rancho Seco					5.9	.44		.9	12.3	3.8		70	68	5.8	<1	<1	29	422	92	5.4	2.5	<3	<4	<7	<3		608			
				1.3	5.7			1.1	11.3	3.6	15			6.6			28										634	.72	.47	
SP 4166 E					5.3	.51		1.1	13.7	5.4		19	394	4.7	<1	<1	36	382	140	10	3.9	<3	<4	<7	<4		466			
				1.6	5.4			1.7	12.5	5.2	26			3.5			35										487	4.2	1.2	
SP 4158					5.7	.49		.9	14.7	5.3		26	260	104	<1	<1	30	364	142	8	19	<3	<4	<7	10		415			
				1.5	5.4			1.0	12.4	4.7	23			104			33										466	3.8	1.1	
SP 4715 E					6.9	.54		.90	14.3	5.5		23	421	7	1.0	<.8	36	355	140	9	5.5	<3	<4	<7	10		415			
				1.4	5.2			1.0	14.5	4.9	22			6			40										375	4.4	1.2	
SP ?					5.4	.28		1.2	11.1	5.2		22	289	4	<1	<.8	38	366	153	10	3.7	<3	<4	<7	3.1		442			
				1.7	5.8			1.0	10.3	5.0	23			1.7			32										573	4.2	1.3	
?" Ag					6.7	<.2		1.4	4.1	6.0		27	91	2.8	<1	<.8	49	296	214	15	5	<3	<4	<7	3.3		530			
				2.1	6.9			1.7	4.4	6.0	25			2.5			48										603	5.5	1.7	
3/4-1½" Ag					8.4	<.2		1.3	4.2	6.0		17	85	2.0	<1	<.8	43	324	165	9	3.6	<3	<4	<7	<3.1		583			
				2.2	7.1			1.7	4.6	5.9	22			[illegible]			44										588	4.6	1.7	
½-¾" Ag					[illegible]	<.2		1.3	4.5	6.6		23	99	3.5	<1	<.8	42	320	173	11	3.6	<3	<4	<7	<3.4		576			
				2.2	7.1			1.5	4.7	6.2	26			2.5			43										546	5.2	1.6	
¼-½" Ag					7.9	<.2		1.2	4.8	7.1		21	97	2	<1	<.8	41	320	191	14	3.5	<3	<4	<7	<3.6		554			
				2.1	7.2			1.8	4.9	6.5	29			2.4			38										564	5.4	1.7	
Fine AG N.					6.3	<.2		1.3	4.3	6.4		20	93	2	<1	<.8	43	340	177	12	4.7	<3	<4	<7	<4.7		542			
				2.2	7.1			1.5	4.0	6.5	25			2.3			41										616	5.2	1.9	
Fine AG S.					6.5	<.2		1.2	4.6	7.3		23	102	2.6	<1	<.8	41	354	193	12	2.1	<3	<4	<7	<3.3		537			
				2.2	7.5			1.5	5.0	7.0	27			2.4			46										611	5.7	2.0	
Crustal Abun				2.8	8.1	.03		2.6	3.6	5.0	25	75	70	1.8	.05	2.5	90	375	165	20	15	.01	.02	.2	2	3	425	6.0	1.2	

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POOR ORIGINAL

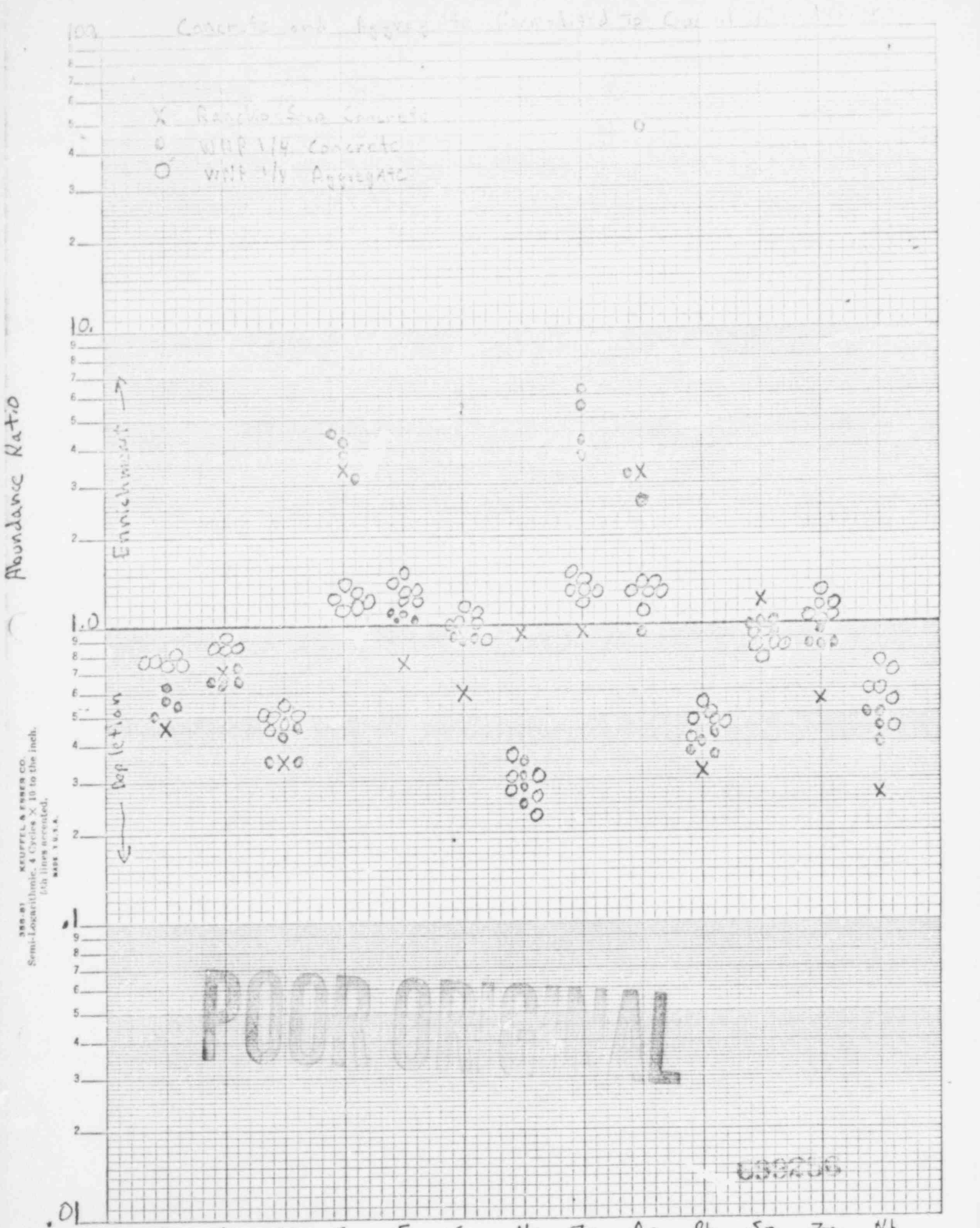
	Di	Ho	Hf	W	Re	Ir	Pb	B	Th	U
Rancho Seco	2.9	<.4	2.7	1.1			8		3.3	1.5
SP4166E	4.7	.9	3.5	.9			8		4.3	1.4
SP4158	4.0	1.2	3.5	<.9			72		3.4	2.0
SP 4715 E	4.2	.9	3.6	<1			9		4.8	1.4
SP X	4.1	.9	3.7	2.3			5		4.4	1.5
3" AG	5.4	1.0	5.1	1.5			9		6.4	1.9
3/4 - 1 1/2" AG	4.7	.9	4.2	<.9			9		4.4	2.0
1/2 - 3/4" AG	5.8	1.0	3.8	1.1			10		4.8	1.0
1/4 - 1/2" AG	6.0	1.3	4.6	<.9			9		4.4	1.5
Fine AG N.	6.1	1.2	4.0	1.1			7		4.5	1.4
Fine AG S.	6.3	.9	4.2	1.2					4.5	1.2
Crustal Abun.	3.0	1.2	3.	1.5	.001	[illegible]	13	.2	7.2	1.8

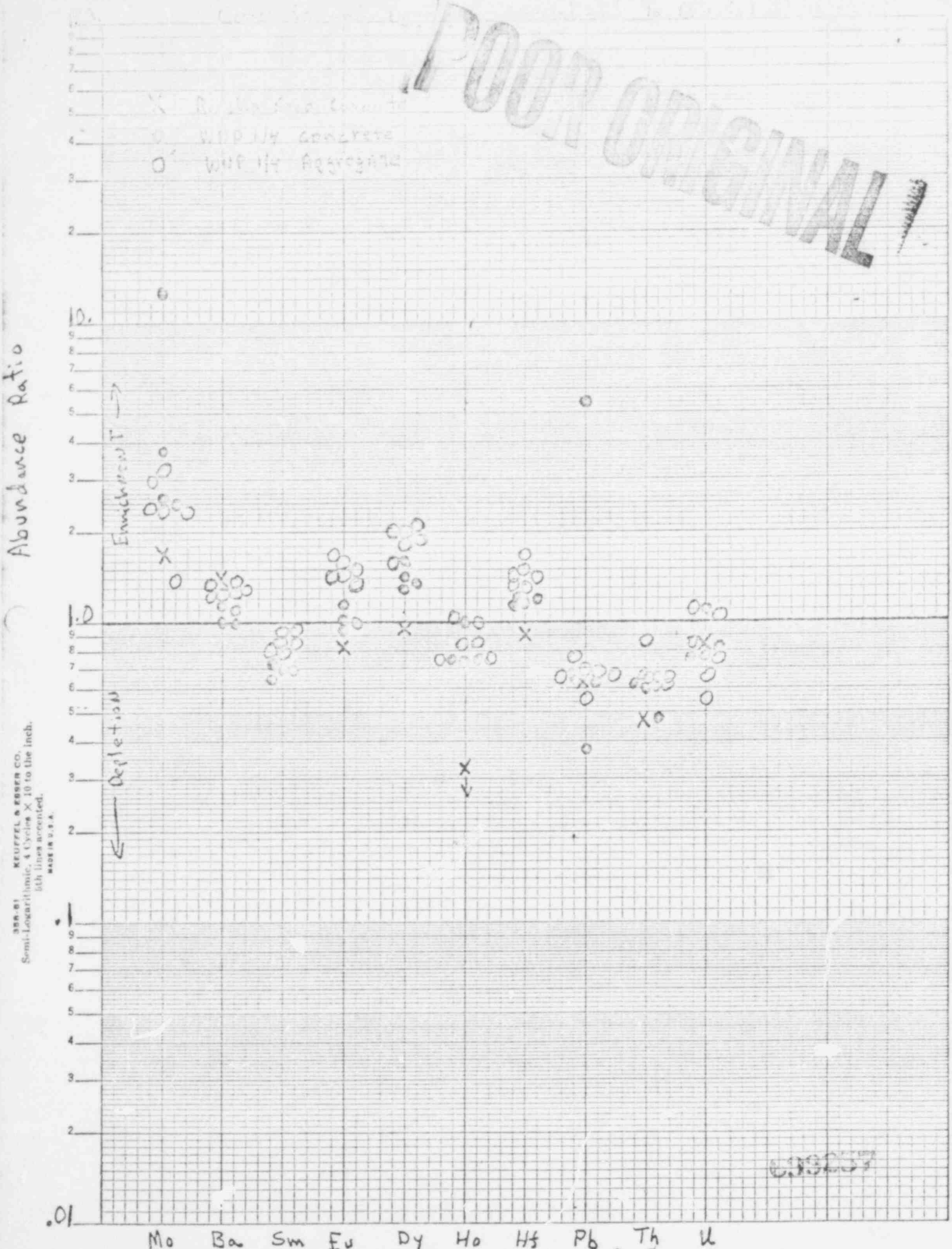
Selected Rock Types Taken From WPPSS 2" Aggregate

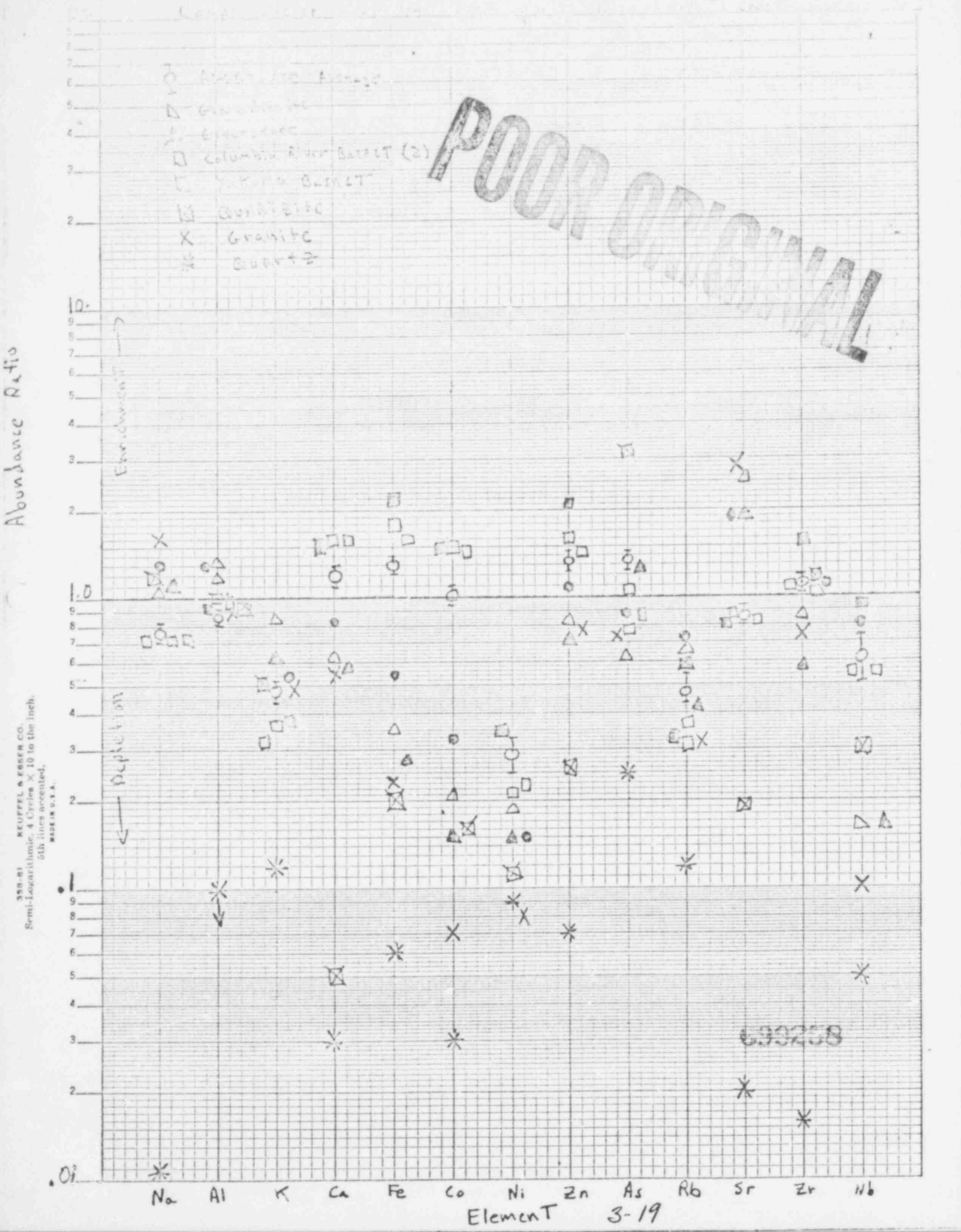
	Li	B	N	% Na	% Al	% S	Cl	% K	% Ca	% Fe	Co	Ni	Zn	As	Se	Br	Rb	Sr	Zr	Nb	Mo	Pd	Ag	Cd	Sn	Cs	Ba	Sc	Eu	Tb
Granodiorite					9.2	<.17		2.3	2.2	1.8		14	57	3	<.7	<.7	57	986	196	3.4	<1	<3	<4	<7	4.3	<4	895			
				2.9	10.9			2.5	2.8	1.7	5.2			1.1			60	1300									924	3.1	.93	
Greenstone					8.3	<.17		1.6	2.1	1.4		11	49	2	<.7	<.7	37	720	95	3.4	2.6	<3	<4	<7	15	<4	640			
				3.2	9.9			2.3	3.1	1.4	3.8			2.3			37	770									697	5.1	1.1	
7 Basalt 1					9.9	<.16		.93	5.7	8.8		16	112	2.2	<.9	<.8	28	307	169	11	4.1	<3	<4	<7	<4	<4	427			
				2.0	8.4			1.6	6.8	8.2	37			1.9			33	340									388	47	1.6	
CRB					10.0	<.17		.84	5.8	8.0		17	104	2	<.8	<.8	26	329	180	11	3.8	<3	<4	<7	2.8	<4	533			
				2.1	7.6			1.5	6.6	7.4	34			1.2			27	380									513	49	1.6	
Monzonite					7.8	<.16		1.4	2.9	2.6		12	76	1.8	<.7	<.7	62	700	179	16	2.6	<3	<4	<7	5.0	<4	615			
				3.7	10.2			2.1	3.1	26	8.2			1.4			64	1120									668	4.2	1.4	
Quartz					<.8			.3	.1	.24		7	5	<1	<.7	<.7	7.3	9	27	1.0	.5	<3	<4	<7	3.3	<4	71			
				.04	3.1			.35	0.3	.26	.8			.45			11.1	<80									85	.64	.15	
Quartzite					7.8	<.11		1.3	.17	1.0		8	18	4	<.5	<.6	48	70	191	6	4.0	<3	<4	<7	3.5	<4	354			
				3.3	7.7			2.1	<.05	1.3	4.0			5.7			53	<200									355	4.5	.45	
Yakima Basalt				2.0	8.6	<.17		1.0	5.7	11.1		26	147	3.8	<1	<.8	33	311	257	19	7.6	<3	<4	<7	7	<4	621			
					7.4			1.2	6.0	10.0	37			1.4			30	<500									657	8.1	2.5	
Granite				4.4	9.2	<.12		1.26	2.0	1.2		6	55	1.6	<.7	<.7	22	1056	123	2	2.6	<3	<4	<7	5.0		1534			
					7.4			1.6	5.0	1.3	1.7			1.3			29	1010									1520	1.6	.7	

RO-1700-1-0 (3-74)

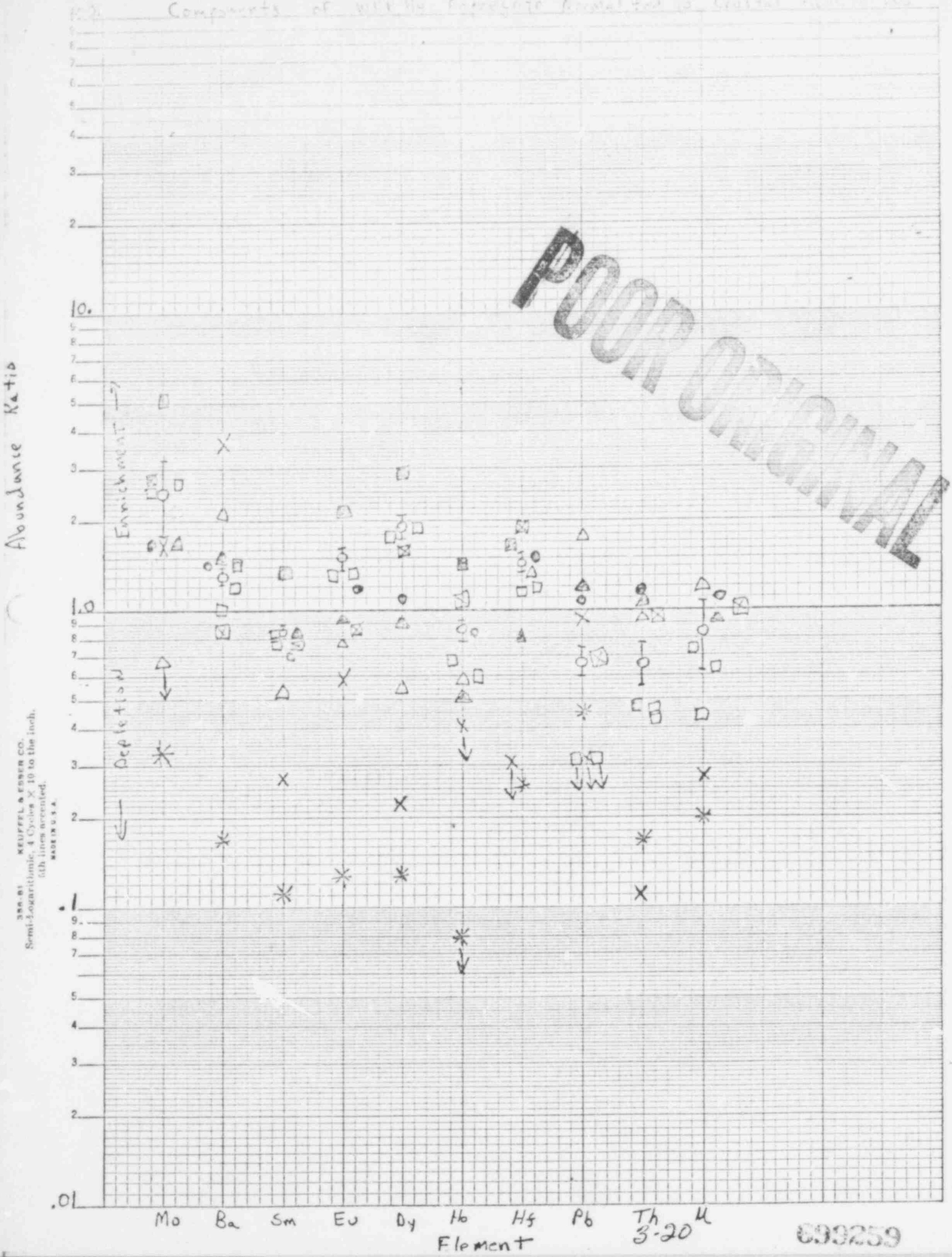
	Dy	Nb	Hf	W	Re	Ir	Pb	Bi	Th	U
Granodiorite	1.6	.7	4.0	<.8			24		6.9	2.2
Greenstone	2.7	.6	2.4	<1.0			16		7.7	1.7
Basalt I	5.8	.7	3.5	<1.0			<4		3.0	1.3
CRB	5.4	.8	3.7				<3.5		3.4	1.1
Monzonite	3.2	1.0	4.5	1.4			14		8.2	2.0
Quartz	.4	<.1	.8	<.2			6		1.2	.36
Quartzite	4.9	1.3	5.6	<1			9		6.6	1.8
Yakima Basalt	8.8	1.7	5.1	1.6			<4.3		3.4	.8
Granite	.7	<.5	2.6	<1			12.3		.8	.5


WNP 1/4 Concrete
WNP 1/4 Aggregate
Abundance Ratio
Enrichment
Depletion
100
10.
1.0
.1
.01
Na
Al
K
Ca
Fe
Co
Ni
Zn
As
Rb
Sr
Zr
Nb
Element
POOR ORIGINAL

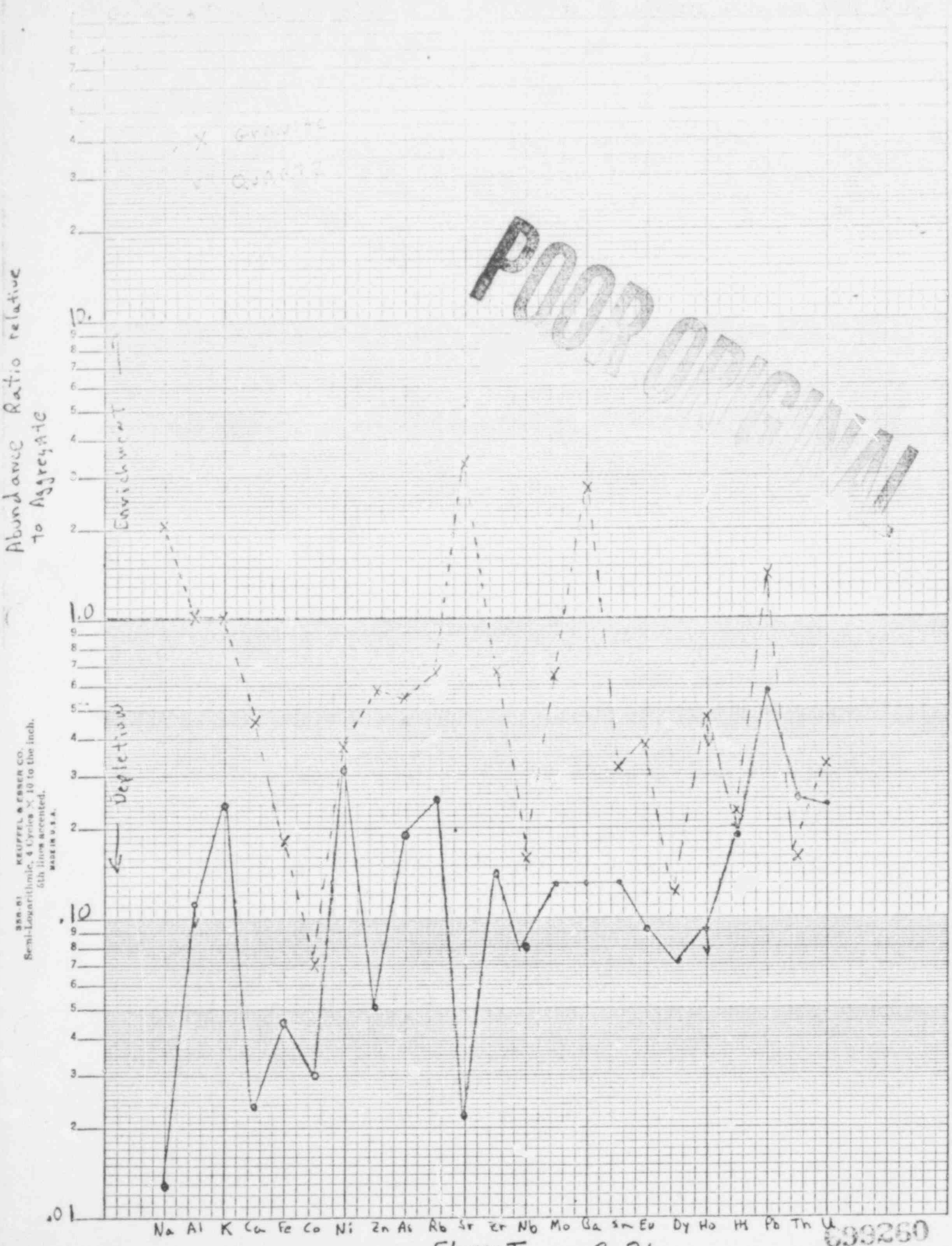

O WNP 1/4 Concrete
O' WNP 1/4 Aggregate
Abundance Ratio
Enrichment →
← Depletion
10.
1.0
.1
.01
Mo
Ba
Sm
Eu
Dy
Ho
Hf
Pb
Th
U
Element



Columbia River Basalt (2)
Granite
Quartz
POOR ORIGINAL
Abundance Ratio
Enrichment
Depletion
10.
1.0
.1
.01
Na Al K Ca Fe Co Ni Zn As Rb Sr Zr Nb
Element 3-19
693258
KEUFFEL & ESSER CO.
Semi-Logarithmic, 4 Cycles X 10 to the inch.
5th lines accented.
MADE IN U.S.A.



Abundance Ratio
Enrichment →
← Depleted
10.
1.0
.1
.01
Mo
Ba
Sm
Eu
Dy
Ho
Hf
Pb
Th
U
Element
KEUFFEL & ESSER CO.
Semi-Logarithmic, 4 Cycles X 10 to the inch.
5th lines accented.
MADE IN U.S.A.



X Granite
Quartz
Abundance Ratio relative to Aggregate
Enrichment
Depletion
1.0
.10
.01
359-81 KEUFFEL & ESSER CO.
Semi-Logarithmic, 4 Cycles X 10 to the inch.
5th lines accented.
MADE IN U.S.A.
Na Al K Ca Fe Co Ni Zn As Rb Sr Zr Nb Mo Ba Sm Eu Dy Ho Hf Pb Th U
Element

ENCLOSURE 4

ACTION ITEMS (B2296)

- o NRC reemphasized that the program should be directed towards understanding the effects of geographical distribution of aggregate used in concretes.
- o In choosing samples to establish the geographical distribution of aggregate near reactors, priority should be given to (1) those facilities to be decommissioned, and (2) areas where reactors are now concentrated. The Northeast and North Central U.S. should receive a high priority.
- o PNL should consider making gross estimates of the distribution of mineral types which constitute the aggregate in concrete by visually inspecting a cross section of the core. This would supplement analysis data on the overall aggregate composition.
- o Attention should be directed to modern reactors. PNL agreed to contact the architectural engineers of the reactor sites of interest to determine the types of concrete which were used (high density versus standard concrete) and also, if possible, determine the sources of the aggregate.
- o Variability in composition of rebar was noted, e.g., as a result of the large influx of rebar from Japan that could produce a great deal of variability vs. the U.S. product.
- o A primary objective should be to place bounds, e.g., upper and lower limits, on aggregate composition so that we may ultimately understand the minimum and maximum long-lived radionuclide concentrations which could be produced.

o NRC agreed to contact Woolam of the U.K. to inform him ι the existence, goals and progress of our program and to ask him to keep us up to date on his progress.

o The origin of reactor vessels should be established and NSS vendors other than Westinghouse contacted for samples so that the issue of variability of construction materials can be addressed. The ASTM guide to composition of construction materials was suggested as a good starting point.

o PNL should contact Jim Divine for an inventory of materials in reactors (e.g., the gross composition of a reactor) and for composition from ASTM standards.

o Data on the composition of construction materials should be transmitted to those individuals who provide us with samples as both a courtesy to them and to improve our rapport.

o PNL should plan the next program review just prior to the NRC workshops to be held this fall and provide NRC with program summary slides for their use at the workshop.

o Jim Divine has several contacts with Canadian colleagues who might help us obtain samples of reactor materials from Canada. PNL should explore this possibility at the earliest possible time.

o The problem of obtaining highly irradiated concrete from a facility was discussed and it appears that this will be difficult to do in the near term. PNL should investigate the feasibility of obtaining a representative concrete sample and subjecting it to a long irradiation, possibly in the N-Reactor. Sufficient material should be irradiated so that some could be archived for future use by ourselves or other researchers.

o PNL should also contact persons in charge of mothballed reactors for sample availability as soon as possible.

Action Items for Proposal to
Evaluate Decontamination as a
Precursor to Decommissioning

1. The modified proposal (189) should provide much more detail on specifically what will be done and how it will be accomplished.

2. Emphasis on the program is
   a. reduction of occupational exposure
   b. reduction of exposure to general public
   c. reduction of waste volume

3. The effect of each decontamination process studies on each item listed in 2 above should be determined.

4. Task 2 should be expanded because it produces the principal results from the project. The investigation should not be limited to existing processes and should utilize duplicate samples obtained from the NRC sponsored project B2299 for experimental assessment of decontamination effectiveness. The proposal should estimate the number of experimental samples required.

5. Decontamination chemicals should be identified, at least generically, and any special considerations for their use presented.

6. The study should include decontamination effectiveness in all parts of the plant, including primary coolant system, cooling towers and soil (although the latter two are intended to represent only a small part of the project effort, e.g., to determine feasibility).

7. Wherever practicable decontamination as a method to permit recycle of components or materials should be considered.

8. Timing of decontamination following facility shutdown is a parameter which should be considered as a variable in the study.