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Nuclear Instruments and Methods in Physics Research A 405 (1998) 569–571

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

SRXFA of element composition of bottom sediments from Teletskoye Lake

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Abstract

Samples of bottom sedimentary material of drilling column 02a from Teletskoye Lake were investigated by synchrotron radiation X-ray fluorescence analysis (SRXFA). Geochemically important elements (Zn, As, Fe, Rb, Sr, Y, Zr, Nb, Ba, La, Ce, Pr, Nd) were determined. Results reveal the difference between sedimental layers associated with rhythmic layer-by-layer oscillation of mineral composition and grain size. A conclusion is drawn about the ability of using of the international geologic standard BIL-1 in studying sediments of Teletskoye Lake by means of a reference sample method in SRXFA.

1. Introduction

The samples for investigation were collected from drilling station St. 02a situated in the axial part of the Northern depression of Teletskoye Lake; the drilling depth of St. 02a is 100 cm, the rate of sedimentation there is approximately 1 mm per year; sediments are mostly presented by terrigeneous mud without significant contamination of biogenic SiO_2.

A first interpretation of the bottom sediment sequences seemed problematic due to the homogeneity of the mineral composition and the small variations of the rock-forming components. Therefore we started with a preliminary differentiation of the geologic section according to colour into layers with a thickness of 2–25 mm and according to morphology and magnetic susceptibility into two units: upper (1–66 cm) and lower (66–103 cm) [1]. Analyses were performed in samples from light and dark layers for both upper and lower units of St. 02a.

2. Experimental

A wide spectrum of geologically informative elements: Zn, As, Fe, Rb, Sr, Y, Zr, Nb, Ba, rare earth elements (REE) La, Ce, Pr and Nd, was determined in 40 samples of St. 02a from Teletskoye Lake.

In the experiment the well known and reliable scheme and procedures were used [2] with some modifications described in Ref. [3]. For example, intervals of approximately undisturbed experimental parameters were determined by evaluating derivative parameters of reference sample spectra and the extent of the reliability of the results for particular elements was calculated versus instability parameters of the SR-beam.

Monochromotized exciting SR energies were approximately 26 and 44 keV; the peak of coherent scattered incident radiation was used as an internal standard for the flow of exciting quanta. A sample of the international geologic standard BIL-1 (terrigeneous mud from the various parts of the Lake Baikal) [4] was used as a reference for quantitative analysis.

3. Results and discussion

The SRXFA of samples from St. 02a reveal the difference between sedimental layers associated with rhythmic layer-by-layer oscillation of mineral composition and grain size. It also confirmed as a whole our preliminary differentiation of two units. The concentrations of the most informative elements and compounds in reference samples BIL-1, PAAS (post-Archean shales of Australia) [5] and in material from St. 02a (mean values, data obtained by SRXFA, ordinary X-ray fluorescence analysis XRFA and instrumental neutron activation analysis INAA) are compared in Table 1.

The geochemical significance of trace elements (such as Y, Zr, Nb, Hf, Sc, Th, REE) is known to grow with the formation of fine-grained clastic material (clay) from the upper crust. It is the high homogeneity of the distribution of REE in PAAS and its proximity to one of the NASC samples and the ES sample that was used as a basis for comparison of the PAAS with BIL-1 and with data for St. 02a of Teletskoye Lake (NASC is a sample of Paleozoic clay shales of North America and ES is a sample of

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PII S0168-9002(96)01057-1

Table 1
Element contents comparison of sediments from St. 02a (mean values, XRFA (*), INAA (**) and SRXFA data) and reference samples BIL-1 and PAAS[a]

	0–66 cm	66–103 cm	BIL-1	PAAS
Rock-forming components (%)				
SiO_2	57.9*	59.2*	61.1	62.8
TiO_2	1.0*	1.02*	0.69	1.0
Al_2O_3	19.2*	18.6*	13.6	18.9
MgO	4.73*	4.44*	2.0	2.2
CaO	1.76*	2.2*	1.85	1.3
Na	1.63*	1.84*	1.47	0.9
K	2.54*	2.31*	1.86	3.05
P_2O_5	0.24*	0.24*	0.35	0.16
LOI	7.37*	6.53*	–	6.0
Mn	0.19*	0.13*	0.31	0.085
Fe	6.8	6.3	4.95	5.05
Trace elements (ppm)				
Sc	29**	22**	13.5	16
Cr	215**	112**	66	110
Co	29	22**	18	23
Zn	105	98	96	85
As	20	15	18	–
Rb	110	106	93	160
Sr	154	173	266	200
Y	37	36	29	27
Zr	175	198	156	210
Nb	12	14	12	19
Cs	11**	5**	5.8	5
Ba	594	547	715	650
La	32	35	45	38
Ce	69	71	80	80
Pr	7.2	7.4	7.5	8.9
Nd	37	36**	39	32
Sm	8.3**	6.3**	7.0	5.6
Eu	2.15**	1.6**	1.4	1.1
Gd	7.9**	6.0**	5.8	4.7
Tb	1.3**	0.9**	0.9	0.77
Dy	(6.0)	(5.0)	4.6	4.4
Ho	(1.3)	(1.0)	1.0	1.0
Er	(3.8)	(3.3)	2.7	2.9
Tm	0.6**	0.45**	0.41	0.4
Yb	3.9**	3.3**	2.9	2.8
Lu	0.55**	0.5**	0.4	0.43
Hf	6.0**	5.5**	3.9	5.0
Ta	1.07**	0.7**	0.84	–
Th	11**	7.0**	12.6	14.6
U	5.2**	3.0**	12	3.1
Geochemical indicators				
La_N/Yb_N	5.5	7.2	10.4	9.2
Eu/Eu*	0.8	0.8	0.65	0.6
Th/U	2.1	2.3	1.04	4.7
La/Th	2.9	5.0	3.55	2.6
La/Sc	1.1	1.6	3.35	2.4
Th/Sc	0.38	0.32	0.93	0.91
K/U ($\times 10^4$)	0.45	0.77	0.16	0.98
K/Rb	21.5	21.8	20	19
Ce/Y	1.88	1.97	2.7	2.95
Ba/Sr	3.9	3.16	2.66	3.3
Sr/Rb	1.4	1.63	2.9	1.27
Zr/Nb	14.7	14.1	13	11

[a] *Data obtained by XRFA, 12 analyses; **data obtained by INAA, 2 analyses; () design data; other data for Teletskoye Lake are obtained by SRXFA, 28 analyses for 0–66 cm and 12 analyses for 66–103 cm.

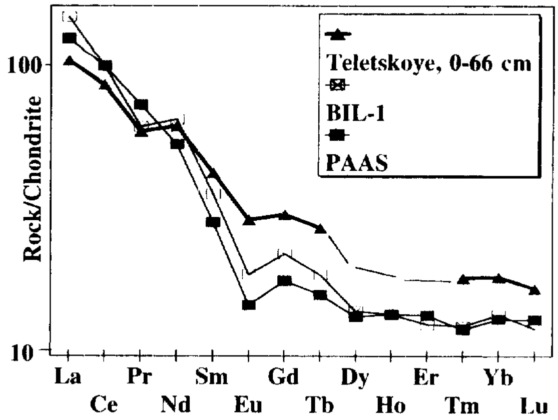

Fig. 1. Ratios of REE concentrations in PAAS, BIL-1 and Teletskoye Lake's sediments to those of chondrite (chondrite concentrations are [6]: $C_{La} = 0.31$, $C_{Ce} = 0.808$, $C_{Pr} = 0.122$, $C_{Nd} = 0.6$, $C_{Sm} = 0.195$, $C_{Eu} = 0.0735$, $C_{Gd} = 0.259$, $C_{Tb} = 0.0474$, $C_{Dy} = 0.322$, $C_{Ho} = 0.0718$, $C_{Er} = 0.21$, $C_{Tm} = 0.0324$, $C_{Yb} = 0.209$, $C_{Lu} = 0.0322$).

Paleozoic clay shales of Europe formed in conditions of continental seas).

The conclusion was made the BIL-1 is proximate enough to PAAS both in REE contents and in Eu/Eu* (0.65 and 0.6) and La_N/Yb_n (10.4 and 9.2) parameters, but sediments of Teletskoye Lake, though being proximate in REE, differ significantly from PAAS in Eu/Eu* (0.8 and 0.6) and in La_N/Yb_N (5.8 and 9.2). Relatively high concentrations of Co, Sc, Y in the sediments of St. 02a suggest a difference from the Lake Baikal (for BIL-1) source of parental rocks. Thus PAAS and BIL-1 correspond to granodiotitic parental rocks; sediments from Teletskoye Lake in turn correspond to relatively basic parental rocks. The ratios of REE concentrations in PAAS, BIL-1 and Teletskoye Lake's sediments to those of chondrite are illustrated in Fig. 1. The curve also reveals the geochemical reason for the fact that a 20% increase of Pr concentration obtained by SRXFA [3] might occur due to the incorrect recommended value for Pr in the geologic standard BIL-1.

SRXFA cannot give concentrations for a *complete* set of trace elements but supplies sufficient information about light REE, Rb, Sr, Y, Zr, Nb, Ba, and some other elements (which may effectively be used to get geochemical characteristics of limnic clays). Thus the use of the geological standard BIL-1 as a reference sample in SRXFA of Teletskoye Lake sediments proves to be reasonable.

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