The first data on the vertical REE distribution in taiga soils of the Russian Far East

Article *in* Doklady Earth Sciences · October 2015

DOI: 10.1134/S1028334X15100104

2 authors:

Semyon Bryanin
Russian Academy of Sciences
21 PUBLICATIONS **125** CITATIONS

Olga Sorokina
Institute of Geology and Nature Management Far Eastern Branch Russian Academy …
11 PUBLICATIONS **62** CITATIONS

ISSN 1028-334X, Doklady Earth Sciences, 2015, Vol. 464, Part 2, pp. 1053–1057. © Pleiades Publishing, Ltd., 2015.
Original Russian Text © S.V. Bryanin, O.A. Sorokina, 2015, published in Doklady Akademii Nauk, 2015, Vol. 464, No. 5, pp. 594–598.

GEOCHEMISTRY

The First Data on the Vertical REE Distribution in Taiga Soils of the Russian Far East

S. V. Bryanin and O. A. Sorokina

Presented by Academician P.Ya. Baklanov July 12, 2014

Received July 22, 2014

Abstract—Coarse humic brown soils formed on different rocks under natural conditions of southern taiga of the Upper Priamur'e were studied. Concentration and distribution of REE in organic-mineral and metamorphic soil horizons were estimated. Soils inherit REE distribution in underlying rocks sitll at lower concentrations. The maximal REE concentrations are found in metamorphic soil horizon and the lowest ones in humic–accumulative. Soil formation processes have an effect on REE concentration in soils, but do not change their distribution.

DOI: 10.1134/S1028334X15100104

We studied coarse-humic brown soils formed on various rocks of the southern taiga in Upper Priamur'e under natural conditions. The studied region includes an interfluve of the Zeya and Selemdzha rivers, which are among the largest in the Amur River basin. The territory is characterized by a typical landscape of Priamur'e with low-mountain relief composed of hilly massifs with large interhill lows. The latter are cuplike depressions with a flat bottom filled with accumulative or denudation material with the thickness reaching 25–30 m. The absolute heights of hills range from 450 to 700 m; the heights of the bottoms of interhill depressions are 300–400 m. The slopes of hills are steep in the upper parts (20°–35°) and more gentle in the lower parts (15°–20°).

According to the schemes of structural zoning, the considered territory is related to the Mamyn terrane (massif) [7]. As is evident from [8], the basement of this terrane is formed of Early and Late Precambrian metamorphic complexes; however, this is not supported by the modern geochronological data. The metamorphic formations are overlain by Lower Cambrian limestone, aleurolite, argillite, Silurian shallow marine terrigenous deposits, and Lower–Middle Devonian terrigenous–carbonate complexes [8].

A significant part of the Mamyn terrane is composed of igneous formations with ages from the Early Precambrian to the Early Mesozoic [8]. They are poorly characterized by the modern geochronological data, except for individual datings for the Paleozoic and Early Mesozoic Complexes [9, 10].

Among the youngest formations are the Upper Triassic and Jurassic marine and continental terrigenous deposits of the Zeya–Depskii trough and Late Mesozoic intrusive and volcanic complexes of the Umlekano–Ogodzhinskii belt [8]. The latter are characterized reliably by the geochronological data (119–108 Ma) [11]. Cenozoic loose deposits of the Amur–Zeya depression are the youngest overlying formations.

The climate of the territory is continental with monsoon features: a humid and hot summer with a cold and snowless winter. The average annual total of precipitation is 630 mm; the average annual temperature is –5.4°C; the duration of the frost-free period is 78 days. The southern taiga larch and larch–birch forests are abundant on the studied area. All these natural factors provide the conditions for the formation of coarse-humic soils of the brown soil series.

The field works were carried out in July–August 2012 in the area of the Orlovka River valley in the basin of the Selemdzha River (Fig. 1). The soil columns were studied on the southern slopes under wood plants. We performed morphological description of soils. Their profiles were subdivided into genetic horizons. An average soil sample with a weight of ~1 kg was collected from each horizon. Rock samples were collected in the same points where soil sampled.

Soil samples were dried, crushed, mixed thoroughly, and then ground. The concentrations of REEs were analyzed at the Institute of Tectonics and Geophysics, Far East Branch, Russian Academy of Sci-

Institute of Geology and Nature Management, Far East Branch, Russian Academy of Sciences, Blagoveshchensk, Amur oblast, Russia
e-mail: bruanin@ascnet.ru

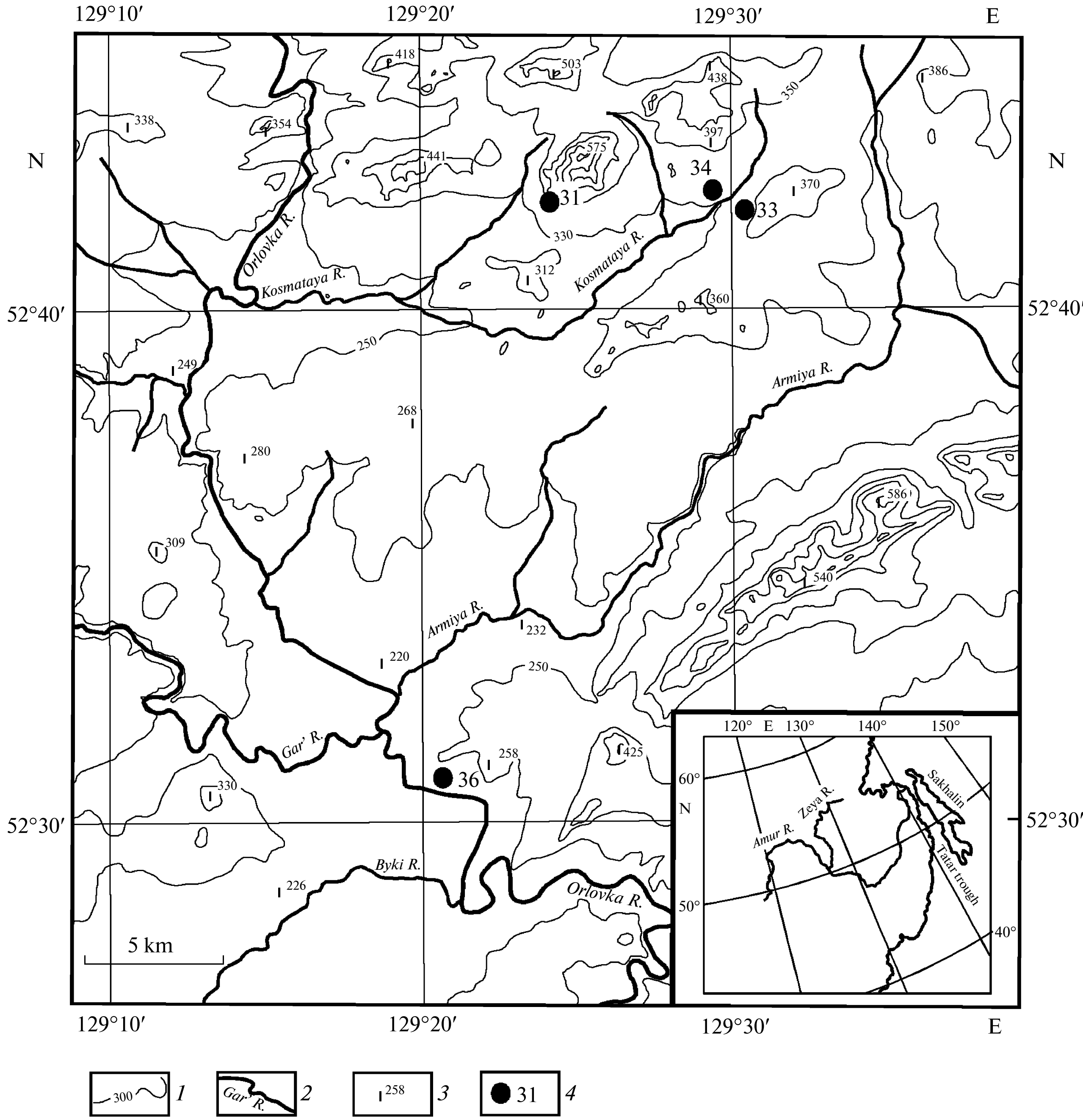

Fig. 1. Scheme of the investigated region. (*1*) Relief horizontals; (*2*) water fluxes; (*3*) absolute heights; (*4*) position and number of soil profile, point of native rock sampling.

ences, by the method of inductive plasma mass spectrometry (ICP-MS); measurements were performed on an Elan DRC II PerkinElmer spectrometer, analysts D.V. Avdeev and L.S. Bokovenko. The analytical error did not exceed 5% RSD.

According to the classification in [12], the coarse-humic brown taiga soils studied are related to the section of structurally metamorphic soils (postlithogenic soils). They are characterized by a coarse-humic horizon 8–10 cm thick, which is overlain by the mineral layer with poor horizontal differentiation. However, the surface coarse-humic horizon in the studied soils has a low thickness (2–4 cm), which is not consistent with the characteristics given above. The low thickness of the surface horizon is explained by frequent ground fires, which prevent its complete formation. Such a feature is typical of most brown soils in Priamur'e [13]. The coarse-humic horizon AO is replaced by the humic–accumulative horizon AY with a thickness of 5–8 cm and with a high concentration of organic

Concentration of REEs in representative samples of soils and rocks (ppm)

Section no.	31			33			36			34		
native rock	rhyolite			rhyolite			gabbro			calcareous sandstone		
horizon	AY	BM	C*	AY	BM	C*	AY	BM	C*	AY	BM	C*
La	24.91	76.85	97.58	19.77	23.04	61.26	19.13	21.15	22.35	16.16	21.23	34.57
Ce	53.72	119.11	188.68	35.99	45.35	144.43	45.40	49.61	48.84	42.01	64.47	63.64
Pr	4.75	15.76	18.71	3.59	4.71	12.51	4.97	5.65	5.63	3.35	4.08	6.92
Nd	18.41	59.86	64.53	13.24	17.61	43.63	20.34	23.33	23.26	12.56	14.74	27.09
Sm	3.27	10.09	12.24	2.22	3.13	6.88	4.18	4.86	4.79	2.42	2.73	5.40
Eu	0.69	1.66	1.91	0.52	0.76	0.95	1.00	1.15	1.29	0.70	0.89	1.13
Gd	3.47	9.73	13.06	2.31	3.12	7.44	4.53	5.38	5.42	2.73	3.47	6.28
Tb	0.38	1.02	1.84	0.26	0.36	1.05	0.57	0.69	0.72	0.33	0.43	0.86
Dy	2.04	4.82	10.54	1.38	1.97	6.20	3.43	4.11	4.31	1.93	2.78	5.03
Ho	0.35	0.79	2.14	0.25	0.35	1.37	0.64	0.80	0.87	0.37	0.56	1.08
Er	1.08	2.43	6.26	0.78	1.06	4.34	2.04	2.53	2.61	1.18	1.86	3.26
Tm	0.14	0.30	0.90	0.10	0.14	0.66	0.28	0.34	0.37	0.16	0.27	0.48
Yb	0.93	2.04	5.90	0.69	0.96	4.54	1.92	2.40	2.51	1.11	1.86	3.23
Lu	0.13	0.28	0.88	0.10	0.13	0.71	0.28	0.34	0.38	0.16	0.28	0.51
ΣREE	114.28	304.76	425.18	81.19	102.70	295.97	108.72	122.35	123.34	85.18	119.66	159.46
ΣLREE	105.75	283.33	383.65	75.33	94.60	269.66	95.02	105.75	106.16	77.20	108.14	138.75
ΣHREE	8.53	21.43	41.53	5.86	8.10	26.31	13.70	16.60	17.18	7.98	11.52	20.71
ΣLREE/ΣHREE	12.40	13.22	9.24	12.85	11.68	10.25	6.94	6.37	6.18	9.67	9.39	6.70
$[La/Yb]_n$	18.20	25.59	11.24	19.46	16.30	9.17	6.77	5.99	6.05	9.89	7.75	7.27
$[La/Sm]_n$	4.75	4.76	4.97	5.56	4.60	5.56	2.86	2.72	2.90	4.17	4.85	3.67
$[Gd/Yb]_n$	3.03	3.85	1.80	2.70	2.64	1.33	1.90	1.81	1.96	2.00	1.50	1.41
Eu/Eu*	1.60	1.98	2.18	0.69	0.73	0.40	0.70	0.68	0.74	0.83	0.87	0.63
Ce/Ce*	0.89	1.27	1.00	0.96	1.00	1.20	1.10	1.08	1.03	1.31	1.56	0.95

C is native rock not subjected to the processes of weathering and soil formation. * Data on the REE concentration in samples of native rocks are provided by A.A. Sorokin.

material. This horizon is underlain by the mineral metamorphic layer with a brown or reddish–brown color and thickness of 20–30 cm. It contains the horizons BM1 and BM2.

The soils studied are similar in morphological structure. They are characterized by the same set of genetic horizons; the profiles of soils are thin (up to 65 cm) with a high content of skeletal material. Since the studied soils are thin and poorly differentiated into horizons, the REE concentrations were analyzed in the humic–accumulative (AY) and metamorphic (BM) soil horizons and in rock not subjected to the processes of weathering (C). The results of the analysis of the REE concentrations in soil profiles and rocks are given in Table 1.

The total REE concentration in various rocks from the studied territory ranges from 123 to 425 ppm. Rhyolite is the most enriched in REEs (296–425 ppm); the lower REE concentrations are typical of gabbro and sandstone (123–159 ppm). Soils preserve the tendencies of REE accumulation inherited from rocks at the lower levels of total concentrations. Thus, the average total REE concentration is 209 ppm in soils on rhyolite and 115 and 102 ppm in soils on gabbro and calcareous sandstone, respectively.

In considering changes in the total REE concentration in individual horizons of the soil profile, we should note that the variations of the concentrations in soils of the humic–accumulative horizons (AY) are small (114–81 ppm). The scattering of value in soil samples collected from metamorphic horizons (BM) is broader (from 102 to 305 ppm). In the soil profile, the total REE concentration reaches the maximum positive correlation with the REE concentration in underlying native rocks ($r = 0.81$, $p = 0.05$, where r is the coefficient of correlation between the REE concentrations in soil of the BM horizon and in native rock; p is the level of significance).

The REE distribution in all the rocks studied is differentiated at $[La/Yb]_n = 4.7–11.2$. A similar charac-

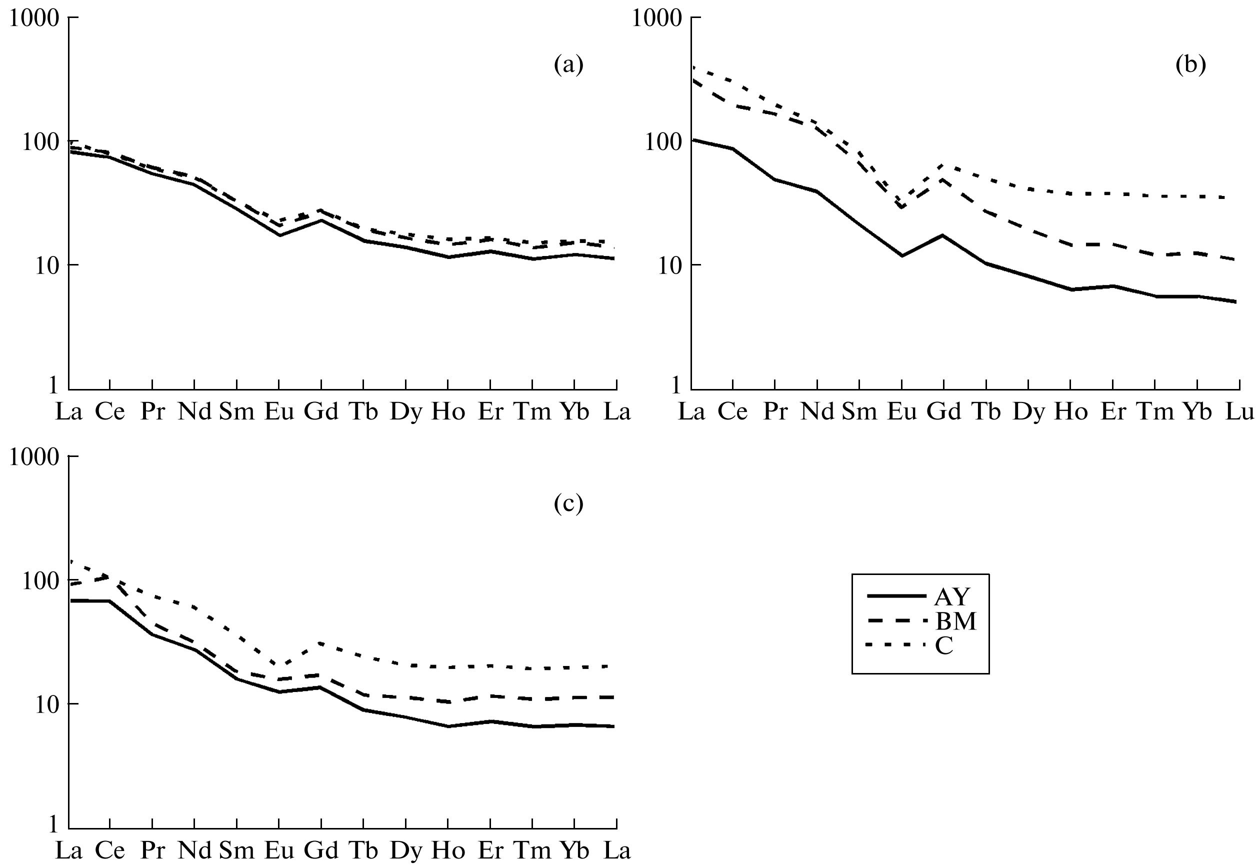

Fig. 2. REE distribution in the soil–rock system. (a) Gabbro, (b) rhyolite, (c) calcareous sandstone. Chondrite composition [14] is applied.

ter of the distribution is observed in soils in which the value of this ratio is 6.7–9.8. An exception is provided by soils formed on only rhyolite: the REE distribution is more differentiated, which is evident from the value of $[La/Yb]_n = 16.3–25.6$. Soils have a clear tendency to enrichment in LREEs in relation to MREEs $[La/Sm]_n = 2.1–5.6$ and less clear enrichment in MREEs in relation to HREEs $[Gd/Yb]_n = 1.4–2.6$. In addition, we observe a progressive decrease in the REE concentrations upwards from underlying rocks to the surface horizons of the soil profile (Fig. 2, table).

Most of the REE spectra in the soils studied have a slight negative Eu anomaly with Eu/Eu* = 1.07–0.63. The Ce anomaly is almost absent in all samples analyzed.

Thus, we obtained the first data on the levels of the concentrations and regularities in the REE distribution in zoned brown taiga soils of the typical low-mountain landscape of the Far East. As is evident from the results of our studies, despite the morphological similarity and relation to the same subtype, brown taiga coarse-humic soils formed under analogous landscape conditions differ significantly by the level of REE concentrations. The concentration of REEs in these soils depends on their concentration in native rocks ($r = 0.74$, $p = 0.05$; r is the coefficient of correlation between the average total REE concentrations in soil and native rock; p is the level of significance). Soils formed on rhyolite accumulate the maximal concentration of REEs; the lower concentrations are typical of soils formed on gabbro and calcareous sandstone. Among all soil samples studied, the maximal REE concentration is observed in the metamorphic horizons (BM), whereas the minimal REE concentration is observed in humic–accumulative horizons (AY). As a whole, the results obtained show that the processes of soil formation do not influence the character of element distribution in soil horizons, but control only the levels of element concentrations.

ACKNOWLEDGMENTS

This study was supported by the Russian Foundation for Basic Research, project no. 14-05-31297.

REFERENCES

1. B. Mourier, J. Poulenard, C. Carcaillet, et al., J. Paleolimnol. **44**, 571 (2010).
2. Yu. N. Vodyanitskii, Pochvovedenie, No. 1, 69 (2012).

3. V. A. Chudaeva and O. V. Chudaev, Tikhookean. Geol. **30** (2), 102 (2011).
4. O. A. Sorokina and N. V. Zarubina, Tikhookean. Geol. **30** (5), 105 (2011).
5. O. A. Sorokina and N. V. Zarubina, Pochvovedenie, No. 6, 681 (2013).
6. O. A. Sorokina and M. N. Gusev, Vestnik SVNTs, No. 4, 36 (2014).
7. L. M. Parfenov, N. A. Berzin, A. I. Khanchuk, et al., Tikhookean. Geol. **22** (6), 7 (2003).
8. *Geodynamics, Magmatism, and Metallogeny of East Russia* (Dal'nauka, Vladivostok, 2006) [in Russian].
9. A. A. Sorokin, N. M. Kudryashov, and A. P. Sorokin, Dokl. Earth Sci. **387A**, 1038 (2014).
10. A. A. Sorokin, N. M. Kudryashov, and Li Tszin'i, Tikhookean. Geol. **23** (5), 54 (2004).
11. A. A. Sorokin, A. P. Sorokin, V. A. Ponomarchuk, et al., Stratigr. Geol. Correlation **17**, 645 (2009).
12. *Classification and Diagnostics of Russian Soils*, Ed. G.V. Dobrovol'skii (Oikumena, Smolensk, 2004) [in Russian].
13. S. V. Bryanin, O. A. Sorokina, Tikhookean. Geol. **34** (3), 104 (2015).
14. W. F. McDonough and S. S. Sun, Chem. Geol. **120**, 223 (1995).

Translated by A. Bobrov