Table 1

Dating of zircon from diamond placers and tuffaceous–sedimentary rocks and xenoliths therein (Grakhanov and Smelov, 2011; Grakhanov et al., 2015b)

Placers and sites	Number of analyses/variations in dating, Ma, average concordant value, Ma (index)		
	Jurassic	Triassic	Paleozoic–Vendian
Quaternary commercial diamond placers			
Ebelyakh	7/147-177, 149 (J_3)	3/222-239, 226, (T_3)	
Diamond-bearing conglomerates of the Pliensbachian Stage (Lower Jurassic)			
Kuoika R., Byuk-Yuryage Creek		8/225 (T_3)	
Raetian and Norian diamond-bearing conglomerates			
Cape Tumul, Tuor-Khaya, 1003-1059		7/221-242, 225 (T_3)	3/257-263, 260 (P_3)
Highly diamondiferous tuffaceous–sedimentary rocks (bottom of the Carnian Stage)			
Bulkur, 165 (BG1), 2011*)		5/230-245, 241,5 (T_2)	8/263-279, 266 (P_2) 1/ 316 (C_2) 1/ 461 (O_2)
Bulkur, BG1-5, 2015*)		20/244 (T_2)	
Bulkur, PG2-2010		34/244 (T_2)	
Khatystaakh, 5014		8/239-256, 239 (T_2)	1/ 276 (P_1)
Ulakhan-Aldzharkhai, 5010		8/220-231, 229, 2 (T_3)	
Cape Tumul, 1000		6/236-247, 242, 4 (T_2)	2/268 (P_2) 1/341 (C_1)
Taas-Krest-Yuryage Creek**)		5/230-240, 236 (T_2)	10/244-259, 251 (P_3) 1/293 (P_1) 623 (V_1) 2/1764-1837, 1800 (PR_1)
Pebbles (xenoliths) from tuffs of the Bulkur anticline at point PG2 (Fig.1)			
Bulkur, PG2-2010, rhyolite–dacites		8/244 (T_2)	
Bulkur, PG2-2010, not determined		8/246 (T_2)	
Bulkur, PG2-2010, andesite-basalts		6/250 (T_1)	

Note. Zircon U–Pb dating was carried out using a SHRIMP II ion microprobe at A.P. Karpinsky Russian Geological Research Institute (VSEGEI) (St. Petersburg) by analysts E.N. Lepekhina and A.N. Larionov.

*) Kimberlite zircon was sampled from the same point, but dated at different times.

**) Unpublished data by VSEGEI (Gosgeolkarta-1000/3, Sheets S-51, 52).

Table 2

Typomorphic features of pyrope from Carnian sedimentary–tuffaceous rocks

Site, sample number, number in Fig. 1	Content in 20-L stream sediment sample	Color, %			Mechanical wear, %	
		orange	red	red-violet	I–II	corrosion
Bulkur, PG2/1, 3	23.702	55.6	17.6	26.4	66.1	33.9
Bulkur, BG1/2, 4	23.155	48.4	30.8	20.8	55.5	44.5
Khatystaakh, 5013, 10	11.498	55.9	29.2	14.9	90.2	9.8
Ul.-Aldzh., 5004, 9	11.498	72.6	0.0	27.4	62.0	38.0

Table 3

Content of chromian pyropes and grains of the diamond association in Carnian volcanosedimentary rocks

Site, point number, number of studied grains	value	$Cr_2O_3 > 5$	$Cr_2O_3 > 7$	$Cr_2O_3 > 10$	$Cr_2O_3 < 2$	Diamond association
Bulkur R., PG2/1, *n* = 523	number	86	31	4	208	7
	%	16.44	5.93	0.76	39.77	1.34
Bulkur R., 5029, *n* = 286	number	79	22	0	45	1
	%	27.53	7.67	0.00	15.68	0.35
Bulkur R., 5020, *n* = 289	number	71	12	0	64	3
	%	24.57	4.15	0.00	22.15	1.04
Khatystaakh R., 5013, *n* = 289	number	45	9	1	57	0
	%	15.57	3.11	0.35	19.72	0.00
Taas-Ary Isle, 5028, *n* = 285	number	84	15	0	53	2
	%	29.47	5.26	0.00	18.60	0.70
Ulakhan-Aldzharkhai R., 5002, *n* = 296	number	71	10	1	44	4
	%	23.99	3.38	0.34	14.86	1.35
Ushat-Khaya R., 5008, *n* = 285	number	24	1	0	67	0
	%	8.42	0.35	0.00	23.51	0.00
Cape Ulakhan-Krest, 1018, *n* = 244	number	67	18	1	100	5
	%	27.46%	7.38%	0.41%	40.98%	2.05%
Cape Tumul, 1000, *n* = 244	number	113	26	0	14	4
	%	38.44%	8.84%	0.00%	4.76%	1.36%

Table 4

Content of kimberlite indicator minerals in Yakutian primary deposits and Carnian tuffaceous–sedimentary rocks

Pipes, rocks	Average content of main kimberlite indicator minerals, wt.%				Pyr/picro relationship
	Total	including			
		pyrope	picroilmenite	Cr-spinel	
1	2	3	4	5	6
Carnian tuffs and tuffaceous–sedimentary rocks					
Bulkur, BG1, total:	9.42	9.11	0.01	0.30	911
including –1 + 0.5	16.26	15.91	0.02	0.33	795.5
–0.5 + 0.25	4.17	3.88	0.005	0.28	776
Bulkur, PG2-2010, total:	33.19	29.32	1.17	2.70	25.1
including –1 + 0.5	52.08	48.80	1.42	1.86	34.4
–0.5 + 0.25	21.19	16.94	1.01	3.24	16.8
Khatystaakh, 5013-2010, total:	1.90	1.87	0.003	0.03	623.3
including –1 + 0.5	3.33	3.31	0.003	0.02	1103.3
–0.5 + 0.25	0.77	0.73	0.002	0.04	365
Ulakhan-Aldzharkhai, 5007, total:	1.03	1.03	–	–	1.0
including –1 + 0.5	1.49	1.49	–	–	1.5
–0.5 + 0.25	0.79	0.79	–	–	0.8
Pronchishchev Ridge, PP3, total:	2.60	2.18	0.03	0.39	72.7
including –1 + 0.5	2.98	2.97	0.003	0.01	990
–0.5 + 0.25	2.21	1.35	0.06	0.80	22.5
Tumul, 1000, total:	1.39	0.37	0.81	0.21	0.5
including –1 + 0.5	1.72	0.46	1.15	0.11	0.4
–0.5 + 0.25	0.69	0.18	0.09	0.42	2
Yakutian primary diamond deposits (Antipin, 1998)					
Mir	1.91	0.67	1.21	0.03	0.55
Internatsional'naya	0.31	0.28	0.01	0.02	28.0
Aikhal	0.02	0.01	0.00.	0.006	3.00
Yubileinaya	0.15	0.1	0.05		2.0
Udachnaya	0.37	0.04	0.28	0.001	
Sytykanskaya	1.80	0.15	1.65	p.з.	0.09

Table 5

Grain-size composition of diamonds from tuffaceous–sedimentary rocks of the Angardam-Tasa complex (data from Nizhne-Lenskoe OJSC)

Sampling site, section in Fig. 1	Sampled in total		Average weight	Including grain-size classes, %							
				–8 + 4		–4 + 2		–2 + 1		–1 + 0.5	
	pcs.	mg	mg	pcs.	mg	pcs.	mg	pcs.	mg	pcs.	mg
Kengdei Member											
Ol'khovyi Creek, 1	146	793.2	5.4	0	0	8	208.0	76	519.2	62	66.0
Bulkur Member											
Pronchishchev Ridge Urasaalakh R., 7	117	122.0	1.0	0	0	0	0	14.5	34.4	85.5	65.6
Cape Tumul, 6	85	4100.0	48.2	3.5	13.5	81.3	86.1	7.0	0.3	8.2	0.1
Bulkur R., BG1, 4	285*)	3155.4	11.1	0	0	36.1	65.9	51.9	33.0	12.0	1.1
Bulkur R., PG2, 3**)	428	6535.1	15.3	0.2	2.6	43.7	82.5	42.5	14.2	13.6	0.7
Khatystaakh R., 10	125	966.0	7.7	0.8	15.5	20.7	56.4	39.7	26.2	38.8	1.9
Ulakhan-Aldzharkhai R., 9	174	1476.0	8.48	0.6	9.8	20.7	58.3	36.8	28.3	41.9	3.6

*) Fragments excluded.

**) A 5.16-ct crystal of variety V was found at this point by geologists of Aerogeologiya Scientific-Production Association.

Table 6

Typomorphic features of diamonds from placers and kimberlites of the Siberian Arctic

Diamond varieties, according to Yu.L. Orlov (1984), %										
Kimberlite pipes and placers	I					II	III	IV	V + VII Ebelyakh type	VIII
	laminar	rounded			sum					
		Urals type	vein type	Sum						
Kimberlites of the northern Siberian diamond-bearing province (Zinchuk and Koptil', 2003)										
D'yanga, T_{2-3} *)	20.6	0.3	53.8	54.1	93.9	3.3	0.0	2.5	0.0	0.0
Leningrad, PZ_{2-3}*)	57.6	6.3	18.7	25.0	95.5	0.0	0.0	0.0	0.0	4.5
Malokuonapskaya, T_{2-3}*)	64.0	4.8	9.6	14.4	97.6	2.0	0.0	0.0	0.0	0.4
Upper Paleozoic, Nuchchayurege Formation (Zinchuk and Koptil', 2003)										
Kyutyungde R., C_1*)	75.9	6.9	4.3	11.2	88.2	0.5	0.0	9.7	0.0	0.0
Triassic placers of the Ladinian Stage of the Kengdei Member										
Western Upper Yana region, Ol'khovyi, T_3^{kn}**)	5.6	63.0	6.3	69.3	77.2	2.4	0.0	0.0	20.5	0.0
Triassic placers of the Carnian Stage of the Bulkur Member										
Cape Tumul, T_3^{os}**)	17.9	35.9	7.7	43.6	62.8	1.3	0.0	2.6	33.3	0.0
Bulkur R., BG1, T_3^{os}**)	19.2	41.6	7.9	49.5	70.6	3.3	0.0	0.5	22.9	0.0
Bulkur R., PG2, T_3^{os}**)	19.7	49.1	4.8	53.9	75.1	2.3	0.0	2.0	22.5	0.0
Khatystaakh R., T_3^{os}**)	21.6	49.9	7.6	57.5	79.1	1.3	0.8	1.3	18.8	0.0
Ulakhan-Aldzharkhai R., T_3^{os}**)	11.2	58.2	8.9	67.1	80.7	2.3	0.0	0.0	19.2	0.0
Pronchishchev Ridge, T_3^{os}*)	18.2	25.4	27.0	52.4	85.7	1.6	0.0	0.0	9.5	0.0
Triassic placers of the Raetian Stage of the Bulunkan Formation (Grakhanov et al., 2010a)										
Watershed of the Nikabyt and Kelimyar Rivers, T_3^{bl}**)	22.4	24.7	8.2	48.4	72.3	6.3	0.0	2.3	19.1	0.0
Early Jurassic placers of the Chymara Formation (Grakhanov et al., 2013)										
Upper reaches of the Kuoika River, J_1cm, **)	21.1	50.0	7.9	57.9	86.9	2.6	0.0	0.0	10.5	0.0
Late Jurassic placers of the Chonoko Formation (Zinchuk and Koptil', 2003)										
Interfluve of the Lena, Molodo, and Syungyude Rivers, J_3cn, *)	27.2	20.4	11.4	31.8	81.2	2.3	0.0	2.3	13.6	0.0
Cretaceous placers (Grakhanov et al., 2007)										
Sinkholes in the Ebelyakh River basin, K_1, *)	19.1	15.6	12.0	27.6	58.2	2.8	0.7	0.7	35.5	2.1
Neogene placers of the Ebelyakh Formation (Grakhanov et al., 2007)										
Karst basin in the upper reaches of the Billyakh River, $N2^{eb}$*)	21.2	10.0	15.7	25.7	55.5	2.2	0.2	0.0	41.6	0.5
Quaternary commercial placers (Grakhanov et al., 2007)										
Ebelyakh River placer, *)	14.1	16.2	20.3	36.5	62.9	3.6	0.2	0.5	30.9	0.2

Note. Analysts: *) V.I. Koptil', Amakinskaya Exploration Expedition, Yakutsk Territorial Geological Survey. **) B.S. Pomazanskii, A.N. Lipashova, and I.N. Bogush, ALROSA PJSC Scientific Research and Geological Exploration Enterprise.

Table 7

Isotopic and trace-element composition of diamonds from tuffaceous–sedimentary rocks of the Bulkur anticline (Grakhanov et al., 2015)

Site, point of observation, section in Fig. 1	Morphologic varieties, according to Yu.L. Orlov (1984)	Number of isotope analysis	$\delta^{13}C$, ‰	Nitrogen concentration	
				A + B1 (ppm)	%B1
I, isotopically heavy					
Bulkur, BG1, 4	thin-layered laminar rhombic dodecahedron	17	–3.6	103.9	25
Bulkur, BG1, 4	laminar octahedron of transitional shape	16	–4.8	110.7	22
Bulkur, PG2, 3	pseudohemimorphic, transitional shape	27	–4.9	51.6	12
Bulkur, BG1, 4	rounded dodecahedroid	9	–5.1	375.1	35
Bulkur, BG1, 4	cubic rhombic dodecahedroid	18	–5.6	1009.1	17
Bulkur, BG1, 4	rounded rhombic dodecahedron with shagreen and SPD	4	–6.2	795.5	25
Bulkur, BG1, 4	rounded rhombic dodecahedron with shagreen and SPD	3	–6.9	747	50
Bulkur, BG1, 4	rounded rhombic dodecahedron with cryptic layering	12	–7.1	932	14
Khatystaakh, KhG5013, 10	rounded dodecahedroid	31	–7	117.3	39
I, isotopically light					
Bulkur, BG1, 4	rounded rhombic dodecahedron with cryptic layering	13	–17.8	1299.8	25
Bulkur, PG2, 3	rounded rhombic dodecahedron with cryptic layering	22	–18.4	1507.9	33
Bulkur, PG2, 3	rounded rhombic dodecahedron with shagreen and SPD	28	–19.3	293.5	29
Bulkur, BG1, 4	rounded rhombic dodecahedron with cryptic layering	1	–19.5	1093	63
Bulkur, PG2, 3	rounded rhombic dodecahedron with cryptic layering	20	–19.8	1977.3	70
Bulkur, PG2, 3	rounded dodecahedroid	21	–21.3	1316.9	85
Bulkur, BG1, 4	rounded rhombic dodecahedron with cryptic layering	11	–21.9	1955.4	80
Bulkur, BG1, 4	rounded rhombic dodecahedron with cryptic layering	5	–22.2	831.1	27
Bulkur, PG2, 3	dodecahedroid fragment	19	–22.2	1214.7	21
Bulkur, PG2, 3	rounded rhombic dodecahedron with cryptic layering	23	–22.8	1279.3	29
II, isotopically heavy and transitional					
Bulkur, PG2, 3	tetrahexahedroid	25	–7.2	551.7	42
Bulkur, PG2, 3	cuboid fragment	26	–7.5	267.3	10
Bulkur, PG2, 3	cube	29	–8.8	293.1	14
Bulkur, BG1, 4	tetrahexahedroid	14	–10.1	238.8	36
V and VII, isotopically light					
Bulkur, BG1, 4	V, rounded dodecahedroid	6	–17.2	900.8	25
Bulkur, BG1, 4	V, rhombic dodecahedron	10	–19.2	1728.2	22
Bulkur, BG1, 4	V, rounded dodecahedroid	7	–19.5	873.8	26
Bulkur, PG2, 3	V, rounded dodecahedroid of distorted shape	24	–20.4	940.3	17
Bulkur, BG1, 4	V, rounded dodecahedroid	8	–20.5	1590.8	30
Bulkur, BG1, 4	V, rhombic dodecahedron	15	–20.8	1716.4	31
Bulkur, BG1, 4	VII, dodecahedroid	2	–21.2	1838.2	30

Ulakhan-Aldzharkhai, UAG5002, 9	V, rounded dodecahedroid	30	–21.6	643	26

Note. SPD, Signs of plastic deformation.

Infrared spectra were analyzed at the Diamond and Precious Metal Geology Institute, Siberian Branch of the Russian Academy of Sciences (Yakutsk), analyst A.E. Molotkov.

Carbon isotope composition was determined at V.S. Sobolev Institute of Geology and Mineralogy, Siberian Branch of the Russian Academy of Sciences (Novosibirsk), analyst V.N. Reutskii.