

Geology of the Recently Discovered Hardy Lake Kimberlites, NWT

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Introduction

Exploration undertaken from 1991 to 1994 by Monopros Limited, a subsidiary of De Beers Consolidated Mines Limited, on the Hardy Lake property led to the discovery of seven kimberlites (McKinlay et al., 1997). Since then another three bodies have been found. The Hardy Lake (HL) property is located ~350km NNE of Yellowknife in the Northwest Territories, Canada. The HL bodies form an eastern extension of the Lac de Gras kimberlite province(s). This area occurs within the Slave Geological Province, an Archaean craton. The kimberlites are hosted by granite and quartz monzonite. The area is covered by glacial deposits from which kimberlite indicator minerals were recovered to aid in the discovery of the kimberlites. The indicator minerals were dispersed in a NW direction by glaciers influenced by the Keewatin Ice Divide centred on the west side of Hudson Bay. The kimberlites all contain microdiamonds, some in significant quantities but the bodies are small, being less than 4 ha. in size.

Mantle-derived xenocrysts

In the HL kimberlites mantle-derived xenocrysts vary in abundance. After olivine, garnet is the dominant mineral. Chromite is generally present in moderate abundances and chrome diopside varies from relatively abundant to rare. In most of the HL kimberlites ilmenite is rare to absent. Most of the garnets are Iherzolitic varieties with Cr₂O₃ contents ranging up to 12 wt.%. TiO₂-rich and TiO₂-poor garnets are both present. Up to 11% of the garnets in any one kimberlite classify as G10. Up to 8% of the garnets are eclogitic and minor megacrystic types also occur. The incompatible element (Ti, Zr) compositions of the garnets show that the kimberlites sampled depleted lithosphere. The garnets commonly have kelyphitic rims. Chromites from HL are comparable in composition to those typically found in kimberlites elsewhere and up to 35% of the grains are similar to diamond inclusion chromites. The latter, together with the common G10 garnets, indicate that the kimberlites sampled the diamond stability field in the mantle which is consistent with the presence of microdiamonds. The kimberlitic ilmenites have Cr₂O₃ contents between 1-4 wt.% and are considered to be metasomatic in origin. The chrome diopsides present are derived from peridotites. A few ultramafic xenoliths were observed in the drillcore.

Geology of the kimberlites

The HL occurrences are classified as kimberlites (*sensu stricto*, Group 1 or archetypal). They contain two generations of olivine which are set in groundmasses composed of monticellite, spinel, perovskite, mica, serpentine and carbonate. The ten kimberlite bodies form two contrasting groups, each with distinct textural characteristics :

- A. the larger bodies which are infilled with inhomogeneous, partly bedded, volcanoclastic kimberlite, and
- B. the smaller bodies which are composed of fresh internally uniform hypabyssal kimberlite that occurs as pipes and small sheet-like intrusions.

Group A, comprising the two most northerly bodies (HL01 and HL02), are volcanoclastic kimberlites composed mainly of single grains of olivine set in a fine grained non-magmatic inter-clast matrix which, in many parts of the kimberlite bodies, resembles shale. Juvenile pyroclastic lapilli are present, mainly in the coarser grained kimberlite. The rocks vary from matrix supported F- to F-MK to clast supported CK (terminology after Field and Scott Smith, this volume). Some bedding, including graded beds, are present. Most observed beds are <1m thick (but may range up to 10m). Each of the pipes displays specific characteristics, for example, with respect to the mantle-derived xenocryst and country rock xenolith contents, and in the nature of the inter-clast matrices. The differences show the unique nature of the two volcanic centres. The kimberlites contain xenoliths of granite but inclusions of shale are much more common. The paucity of granite clasts shows that the pipes were excavated into the country rock prior to their infilling by kimberlitic material. The shale must have been derived from sedimentary country rocks that covered the Archaean basement at the time of kimberlite emplacement but have since been eroded. Many of the sediment xenoliths were poorly consolidated when they were incorporated into the kimberlite. Some fossil wood is also present. The hypabyssal kimberlites (Group B) vary from sparsely macrocrystic to macrocrystic in texture. They contain common xenoliths of granite (usually <1cm) but in three of the kimberlites there are also rare irregular xenoliths that resemble sedimentary material.

Palynology

Palynomorphs recovered from individual sedimentary clasts hosted by the volcanoclastic kimberlites usually have restricted age ranges between 3 and 10 Ma. (99-94, 97-96, 96-93, 93-90, 88-85, 84-75, 78-67 and 74-67 Ma.). These data suggest that the sediment clasts represent xenoliths derived from many different stratigraphic units of the now eroded sedimentary cover rocks. The total range in ages of the sediments (99-67 Ma.) spans most of the Upper Cretaceous showing that during this period the Western Interior Seaway extended over this area of the Slave. It is probably not coincidental that this is also the period of overall highest sea levels in the Seaway. Similar results were found by Nassichuk and McIntyre (1995) for other pipes in the Lac de Gras area west of HL. It is interesting to consider what thickness of sediments may have been present at the time of kimberlite emplacement and what their possible effect on the near surface emplacement processes would have been in terms of the concepts discussed by Field and Scott Smith (this volume). Another fascinating aspect of these, and other kimberlites in the Lac de Gras area, is why some kimberlites formed volcanoclastic infilled pipes while others are hypabyssal. The HL sediment xenolith data also show that the maximum age of emplacement of these kimberlites is 74-78 Ma..

Samples of the host volcanoclastic kimberlite which contained no macroscopically visible sediment xenoliths all contained microfossils. In contrast to the single sediment xenoliths discussed above, each sample of the host kimberlite yielded palynomorphs with a wide range of ages of between 30 and 60 Ma.. This shows that the inter-clast matrix of the volcanoclastic kimberlites is composed of a blend of disseminated shale from mixed stratigraphic sources in the sedimentary cover. This result strongly suggests that the final deposition of the kimberlitic material containing the blended shaly matrix was by re-sedimentation processes. This conclusion is supported by the presence of probable armoured lapilli and a variety of 'mudballs' composed of a mixture of shale and kimberlitic constituents. The presence of armoured lapilli and 'mudballs' also suggests a wet environment of deposition. The total range in ages of the microfossils found in the host kimberlite is 116-55 Ma. and includes examples younger than those found among the analysed xenoliths. Palynomorphs with age ranges <67Ma. were only found in HL01. There are two possible explanations for these features.

Firstly, the kimberlites could be younger than 74-78 Ma.. An age of 52 Ma. has been reported for another kimberlite in the Lac de Gras area (Nassichuk and McIntyre, 1995). If so, the uppermost country rock sediments may not have included 67-55 Ma. rocks or the rocks of this age were so poorly consolidated that they disintegrated when incorporated into the kimberlite. It is also possible that the sampling did not include such xenoliths. The second explanation is that the kimberlites were emplaced at ~74 Ma.. Heaman et al. (1997) reported an age of 74 Ma. for another Lac de Gras kimberlite. If so, the HL pipes could have been infilled by resedimentation over a prolonged period of time, long enough to incorporate palynomorphs from the surface long after the kimberlite eruption.

Most of the microfossils from the sediment xenoliths (97-73 Ma.) are marine. However, the youngest microfossils from each of the host kimberlites are terrestrial (66-55 Ma. at HL01; 74-67 Ma. at HL02). This suggests that the period 74-66 Ma. was a time of regression. This is consistent with the last overall main regression of the Western Interior Seaway which occurred at ~71Ma.. After this time terrestrial conditions probably predominated. Given the lack of a precise age of eruption for the HL bodies, the environment at the time of emplacement of the kimberlite cannot be determined.

A few sediment-like xenoliths from two of the hypabyssal kimberlites yielded sparse terrestrial organic material with ages of 108-97, 116-97 and possibly 67 Ma.. Further work is required, but the data suggest that the xenoliths contain Cretaceous organisms derived from the sedimentary cover and that the magmatic kimberlite must have penetrated some, or all, of the Cretaceous sediments that were present at the time of emplacement. The magma must then have withdrawn to its present location. Also, the organisms appear to have been subjected to a maximum temperature of only 300° C which is unexpected. Possible olivines were observed within some of the xenoliths suggesting that they may not be simple country rock clasts.

Conclusions

Ten kimberlites were discovered on the HL property which include two volcanoclastic pipes with the remainder being of hypabyssal-facies. Palynology of sedimentary xenoliths from within the volcanoclastics show that the kimberlites were emplaced after 74-78Ma. and that the Great Western Interior Seaway covered this part of the Slave during most of the Cretaceous. The volcanoclastic kimberlites may have been deposited by resedimentation processes (possibly long lived) into a previously excavated pipe. Cretaceous palynomorphs have been recovered from rare xenoliths within hypabyssal kimberlites.

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EXTENDED ABSTRACTS

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SOUTH AFRICA

	Page No
Abrakhrimov, M.Z., Kouznetsova, E.I., Traskin, V.Yu.	1
Abe, N., Arai, S., Yurimoto, H.	4
Afanasiev, V.P., Pokhilenko, N.P., Logvinova, A.M., Yefimova, E.S.	7
Agashev, A.M., Fomin, A.S., Watanabe, T., Pokhilenko, N.P.	9
Agashev, A.M., Watanabe, T., Kullgin, S.S., Pokhilenko, N.P., Orihashi, Y.	11
Ananiev, V.A., Kullgin, S.S., Reimers, L.F., Khlestov, V.V.	14
Andre, L., Shatsky, V.S., De Corte, K., Sobolev, N.V., Navez, J., Jagoutz, E.	17
Andronikov, A.V., Foley, S.F., Melzer, S.	20
Antonyuk, B.P., Mironov, V.P.	23
Araujo, A.L.N., Gaspar, J.C., Bizzi, L.C.	26
Araujo, D.P., Gaspar, J.C., Garg, V.K.	29
Arima, M.	32
Ashchepkov, I., Salters, V., Andre, L.	35
Bailey, L., Helmstaedt, H.H., Peterson, R.C., Mandarino, J.A., Letendre, J.P.	37
Barashkov, Y.P., Talnikova, S.B.	40
Barron, K.M., Logvinova, A.M., Sobolev, N.V.	43
Barron, L.M., Lishmund, S.R., Oakes, G.M., Barron, B.J.	46
Barry, T.L., Kempton, P.D., Saunders, A.D., Windley, B.	49
Barth, M.G., Rudnick, R.L., Spicuzza, M.J., Valley, J.W., Haggerty, S.E.	52
Baumgartner, M.C., Neuhoﬀ, L.	55
Beard, A.D., Mason, P.R.D., Downes, H.	58
Beard, A.D., Millidge, H.J.	61
Bell, D.R., Mofokeng, S.W.	64
Belousova, E.A., Griffin, W.L., O'Reilly, S.Y.	67
Ben Ismail, W., Mainprice, D.	70
Ben Ismail, W., Mainprice, D., Barruol, G., Boyd, J., Vaucher, A.	73
Berg, G.W.	76
Berg, G.W.	79
Berg, G.W., Carlson, J.A.	81
Berryman, A.K., Stiefenhofer, J., Shee, S.R., Wyatt, B.A.	84
Bizzi, L.A., Pimentel, M.	87
Bordon, V.	89
Bordon, V., Astapenko, V.	90
Bovkun, A.V., Garanin, V.K., Kudriavtseva, G.P., Possukhova, T.V.	91
Bovkun, A.V., Garanin, V.K., Kudriavtseva, G.P., Possukhova, T.V.	94
Bovkun, A.V., Garanin, V.K., Kudriavtseva, G.P., Possukhova, T.V.	97
Boyd, F.R., Pearson, D.G., Mertzman, S.A.	100

Author	Title	Page No's
Brown, J.W., Butcher, A.R.	Textural and Petrological Variation Within the Crater Facies Kimberlite Bodies of the Fort à la Corne Province, Saskatchewan, Canada.	103
Brown, R.W., Gallagher, K., Griffin, W.L., Ryan, C.G., de Wit, M.C.J., Belton, D.X., Harman, R.	Kimberlites, accelerated erosion and evolution of the lithospheric mantle beneath the Kaapvaal craton during the mid-Cretaceous.	105
Budaev, D.A.	<<Populational>> model of kimberlites: an application to diamondiferous kimberlites of regions with various geodynamic history.	108
Budaev, D.A., Dolgunin, A.V. Fomin, A.S.	An algorithm of kimberlite diamondiferousness estimations.	111
Butanova, G.P., Griffin, W.L., Kaminsky, F.V., Davies, R., Ryan, C.R., Andrew, A., Spetsius, Z.V., Zakharchenko, O.D.	Diamonds from Zamitsa and Dalnaya kimberlites (Yakutia): Their nature, growth history, and lithospheric mantle source.	113
Butanova, G.P., Shelkov, D.	Nature of eclogitic diamonds from Yakutian kimberlites: evidence from isotopic composition and sulphide inclusion chemistry.	116
Burgess, R., Phillips, D., Harris, J.W., Robinson, D.N	Antarctic diamonds in South-Eastern Australia? Hints from ⁴⁰ Ar/ ³⁹ Ar Laser probe dating of clinopyroxene inclusions from Copeton diamonds.	119
Burgess, S.R., Harte, B	Tracing Lithosphere Evolution through the analysis of Heterogeneous G9/G10 Garnets in Peridotite Xenoliths.	122
Carlson, J.A. Kirkley, M.B., Thomas, E.M. Hillier, W.D.	Recent major kimberlite discoveries in Canada.	127
Carlson, R.W., Irving, A.J., Hearn, B.C Jr.	Peridotite Xenoliths from the Williams Kimberlite, Montana: Implications for Delamination of the Wyoming Craton Lithosphere	132
Carlson, R.W., Pearson, D.G., Boyd, F.R., Shirey, S.B., Irvine, G., Menzies, A.H., Gurney, J.J.	Regional Age Variation of the Southern African Mantle: Significance for Models of Lithospheric Mantle Formation	135
Carlson, S.M., Hillier, W.D., Hood, C.T., Pryde, R.P., Skelton, D.N	The Buffalo Hills Kimberlite Province, North-central Alberta, Canada.	138
Cartigny, P., Harris, J.W., Javoy, M	Eclogitic, Peridotitic, Metamorphic Diamonds and the Problems of Carbon Recycling.	141
Channer, D.M.deR., Cooper, R.E.C., Kaminsky, F.	The Guaniamo diamond region, Bolivar state, Venezuela: a new kimberlite province.	144
Cherny, S.D., Fomin, A.S., Yanygin, J.T., Banzeruk, V.I., Kornilova, V.P.	Geology and composition of the Nakyn field kimberlite pipes and diamond properties (Yakutia).	147
Chesley, J.T., Rudnick, R.L., Lee, C.-T.	Longevity of Cratonic Mantle Beneath an Active Rift: Re-Os evidence from Xenoliths from the Tanzanian East African Rift.	149
Chinn, I.L., Gurney, J.J., Harte, B., Fitzsimmons, I.C.W., Milledge, H.J	Nitrogen contents of diamond plates : a comparison of FTIR and SIMS analyses	152
Chinn, I.L., McCallum M.E., Harris C., Milledge, H.J., Gurney, J.J.	C02 - bearing diamonds in eclogite xenoliths from the Sloan 2 kimberlite, Colorado	155
Chinn, I.L., Milledge, H.J., Gurney, J.J.	Diamonds and inclusions from Jagersfontein kimberlite	156
Clarke, J., Sobie, P.A., Wilkes, T.A., Zweistra, P	The Geology and Economic evaluations of the Lihobong kimberlites, Lesotho.	158
Cookenboo, H.O.,	Emplacement history of the Jericho kimberlite pipe, northern Canada.	161
Cookenboo, H.O., Kopylova, M.G., Daoud, D.K.	A chemically and texturally distinct layer of diamondiferous eclogite beneath the central Slave craton, northern Canada.	164
Corbett, I.B. McMillan, I.K	From Shore to Shelf and Back Again.	167
Davies, R., Griffin, W.L., Pearson, N.J., Andrew, A., Doyle, B.J., O'Reilly, S.Y.	Diamonds from the Deep: Pipe DO-27, Slave Craton, Canada.	170
Davies, R.M., O'Reilly, S.Y., Griffin, W.L.	Characteristics of Alluvial Diamonds from Bingara and Wellington, Eastern Australia.	173
Davies, R.M., O'Reilly, S.Y., Griffin, W.L.	Dynamic Growth Structures in Diamonds from Bingara, NSW, Australia.	176
Dawson, J.B.	Melting and Metasomatism in Upper Mantle Peridotite Xenoliths from Labait, North-central Tanzania, and contrasting Metasomatic styles in the Tanzanian Lithospheric Mantle.	179
de Bruin, D	Inclusion Bearing Cr-poor and Cr-rich Garnet Megacrysts from the Group II Swartuggens Kimberlite.	181
De Corte, K., Cartigny, P., Shatsky, V.S., De Paepe, P., Sobolev, N.V., Javoy, M.	Microdiamonds from UHP Metamorphic rocks of the Kokchetav Massif, Northern Kazakhstan: FTIR spectroscopy, C & N isotopes and Morphology.	184
Deines, P	Intra-and inter-Mineral Oxygen Isotope Variations in Kimberlitic Zircons.	187
Demaiffe, D., El Fadli, S., Andre, L.	Geochemical and isotopic (Sr, Nd) study of eclogite nodules from the Mbuji Mayi kimberlite, Kasai, Congo. Nature of the protoliths and evidence for mantle metasomatism.	190
De Meillon, L., Bristow, J.W	Some Characteristics of High Level Tertiary Age Alluvial Terraces along the Orange River between the towns of Douglas and Prieska, Northern Cape Province, South Africa.	193
De Wit, M.C.J., Morelli, C., Skinner, C.P.	A reinterpretation of the Lichtenburg diamond deposits.	195
Omitriev, A.N., Dyatlov, V.L., Litasov, K.D.	Physical model of kimberlite pipes formation: new constraints from theory of non-homogenous physical vacuum.	196
Doyle, B.J., Kivi, K., Scott Smith, B.H.	The Tli Kwi Cho (DO27 and DO18) Diamondiferous Kimberlite Complex Slave Craton, Northwest Territories, Canada	199
Edler, E., Winter, F., Edwards, R.	The Rosario do Sul Kimberlitic Province, Rio Grande do Sul State, Southern Brazil.	202
El Fadli, S., Demaiffe, D.	Petrology, mineral chemistry and thermobarometry of eclogite nodules from the Mbuji Mayi kimberlite, Kasai, Congo: significance of kyanite-cpx intergrowths.	205

Erinchev, Y.M., Milshtein, E.D., Saltykov, O.G., Verzhak, V.V.	Local depressions in Country Rock of Kimberlites as a New Exploration Criteria (by the Example of Zolotitsa Field, Arkhangelsk, Russia).	208
Field, M., Scott Smith, B.H.	Near surface emplacement of kimberlites: contrasting models and why.	211
Field, M., Scott Smith, B.H.	Textural and Genetic Classification schemes for kimberlites: a new perspective	214
Foley, S.F., Glaser, S.M., Andronikov, A.V	Non-cratonic garnet peridotites from rifted continental settings in Vitim, Siberia (Baikal Rift and East Antarctica) (Lambert-Amery Rift).	217
Foley, S.F., Musselwhite, D.S., van der Laan, S.R.	Melting processes in veined lithospheric mantle in cratonic and non-cratonic settings.	220
Friese, A.E.W.	Structural control on kimberlite genesis and crustal emplacement within South Africa and the Kaapvaal Craton during the Cretaceous	224
Friese, A.E.W.	Tectonic evolution and intra-cratonic alkaline magmatism within the central Kaapvaal Craton during the Mesoproterozoic.	227
Fung, A.T.	Petrochemistry of upper mantle eclogites from the Grizzly, Leslie, Pigeon and Sable kimberlites in the Slave Province, Canada.	230
Garanin, V.K., Kudriavtseva, G.P., Possukhova, T.V.	Diamonds of Arkhangelsk kimberlite province (review).	233
Garanin, V.K., Kudriavtseva, G.P., Vasilyeva, E.R.	The fundamental study of garnets: application for prospecting and economical estimation of diamond bearing kimberlites.	236
Gaspar, J.C., Araujo, D.P., Melo, M.V.L.C.	Olivine in Carbonatitic and Silicate Rocks in Carbonatite Complexes	239
Gaspar, J.C., Teixeira, N.A., Steele, I.M.	Cathodoluminescence of Juina Diamonds.	242
Gaul, O., O'Reilly, S.Y., Griffin, W.L.	Lithosphere Mapping in Eastern Australia.	245
Geiger, C.A.	Could the Effect of Order-Disorder in Garnet be Important for Upper Mantle Petrology?	248
Gibson, S.A., Thompson, R.N., Dickin, A.P	Subcontinental mantle plume impact and kimberlite genesis.	250
Girnis, A.V., Stachel, T., Brey, G.P. Harris, J.W., Philips, D.	Internally consistent geothermobarometers for garnet harzburgites.	253
Gonzaga, G.M., Gaspar, J.C., Araujo, D.P.	³ He and ¹⁰ Be Isotopes as a Diamond Exploration Tool: Some thoughts Based on Literature Data	256
Graham, I., Burgess, J.L., Bryan, D., Ravenscroft, P.J., Thomas, E., Doyle, B.J., Hopkins, R., Armstrong, K.A.	The Diavik Kimberlites - Lac de Gras, Northwest Territories, Canada.	259
Graham, S., Lambert, D.D., Shee, S.R., Smith, C.B., Hamilton, R.	Re-Os and Sm-Nd Isotope Systematics of Alkaline Ultramafic Rocks, Xenoliths and Macrocrysts from the Earraheedy Basin, Yilgarn Craton.	262
Graham, S., Lambert, D.D., Smith, Chris.B., Shee, S.R., Reeves, S.J.	Re-Os Isotope Systematics of Oxide Xenocrysts and Peridotite Xenoliths from the Kimberlites and the Argyle Lamproite, Kimberley Block, Australia: Implications for the Evolution of the Continental Lithospheric Mantle.	265
Greenwood, J.C., Gibson, S.A., Thompson, R.N., Weska, R.K., Dickin, A.P	Petrogenesis of Cretaceous Kimberlites from the Paranatinga Region, Central Brazil.	268
Griffin, W.L., Doyle, B.J., Ryan, C.G., Pearson, N.J., O'Reilly, S.Y., Natapov, L., Kivi, K., Kretschmar, U., Ward, J.	Lithosphere Structure and Mantle Terranes: Slave Craton, Canada.	271
Griffin, W.L., Win, T.T., Davies, R., Wathanakul, P., Andrew, A., Metcalfe, I.	Diamonds from Myanmar and Thailand: Characteristics and Possible Origins.	274
Grütter, H.S.	Chrome-calcium, Magnesium-number and Yttrium characteristics of garnets in depleted Lherzollitic, Harzburgitic and Dunitic mantles.	277
Grütter, H.S., Apter, D.B	Kimberlite-and lamproite-borne chromite phenocrysts with "diamond-inclusion"-type chemistries.	280
Grütter, H.S., Apter, D.B	Garnet xenocryst chemistries in a traverse from Eendekuil to Kimberley over the south-western margin of the Kaapvaal craton.	283
Grütter, H.S., Quadling, K.E	Some comments on the (ab)use of sodium in garnet to predict eclogitic diamond potential.	287
Gurney J.J., Moore R.O., Bell D.R.	Mineral associations and compositional evolution of Monastery kimberlite megacrysts	290
Haggerty, S.E., Fung, A.T.	Orbicular Oxides in Carbonatitic Kimberlites: High Pressure Autoliths or Low P Liquid Immiscibility?	293
Hamilton, M.A., Pearson, D.G., Stern, R.A., Boyd, F.R.	Constraints on MARID petrogenesis: SHRIMP II U-Pb zircon evidence for pre-eruption metasomatism at Kampfersdam.	296
Harlow, G.E.	Interpretation of Kcpx and CaEs in Clinopyroxene from Diamond Inclusions and Mantle Samples.	299
Harmer, R.E	Carbonatite magmas in the mantle: Evidence and relationship to kimberlites, orangeites and lamproites.	302
Harris, P.D., Courtnage, P.M	The effects of Regolith-Landform development in diamond exploration: spectral investigation.	305
Harte, B., Hutchison, M.T., Lee, M., Harris, J.W	Inclusions of (Mg,Fe)O in Mantle Diamonds	308
Hatton, C.J.	The Difference between Sheared and Granular Peridotites.	311
Hatton, C.J.	The Kimberlite-Megacryst link at Monastery Mine.	314
Hauri, E.H., Pearson, D.G., Bulanova, G.P., Milledge, H.J	Microscale variations in C and N isotopes within mantle diamonds revealed by SIMS.	317
Hausel, W.D., Kucera, R.E., McCandless, T.E., Gregory, R.W	Mantle-Derived Diatremes in the Southern Green River Basin, Wyoming, USA	320
Heaman, L., Teixeira, N.A., Gobbo, L., Gaspar, J.C.	U-Pb Mantle Zircon Ages for Kimberlites from the Juina Paranatinga Provinces, Brazil.	322

	Title	Page No's
Heaman, L.M., Creaser, R.A., Cookenboo, H.O.	Zircons from eclogite in the Jericho Kimberlite Pipe, northern Canada: Evidence for Proterozoic High Pressure Metamorphism Beneath the Slave Province.	325
Hearn, B.C. Jr	Peridotite xenoliths from Porcupine Dome, Montana, USA: Depleted subcontinental lithosphere samples in an olivine-phlogopite-carbonate magma.	328
Helmstaedt, H.H., Harrap, R.M.	Tectonic Aspects of the Kimberlite - Diamond - Upper-Mantle-Sample Connection: Does a coherent Model evolve?	331
Hutchison, M.T., Cartigny, P., Harns, J.W.	Carbon and Nitrogen Compositions and Cathodoluminescence Characteristics of Transition Zone and Lower Mantle Diamonds from Sao Luiz, Brazil.	336
Ionov, D.A., Griffin, W.L., O'Reilly, S.Y.	Garnet peridotite xenoliths in alkali basalts from Siberia and Mongolia: a comparison of lithospheric mantle compositions in cratonic and younger terrains.	339
Iouchko, N.A., Kremenetsky, A.A., Kouznetsov, I.I.	Nature of Diamonds, Melts and Fluids in the Ring Structures: Endogeneous Explosion vs. Impact Process.	342
Irvine, G.J., Pearson, D.G., Carlson, R.W., Boyd, F.R.	Platinum Group Element Constraints On The Origin Of Cratonic peridotites: A Study Of Kimberley Peridotite Xenoliths.	346
Irving, A.J., Kuehner, S.M.	Petrology and Geochemistry of the Ruby Slipper Lamproite, Western Montana: A Leucite-Bearing, Ultrapotassic Magma in an Eocene Continental Arc.	349
Izraeli, E., Schrauder, M., Navon, O.	On the Connection between Fluid and Mineral-Inclusions in Diamonds.	352
Izraeli, E., Wilcock, I.C., Navon, O.	Raman Shifts of Diamond Inclusions - A Possible Barometer.	355
Jacob, D.E., Foley, S.F.	Evidence for Archean Ocean Crust with Island Arc Signature from Diamondiferous Eclogite Xenoliths.	358
Jacob, D.E., Kjarsgaard, B., Horn, I.	Trace element concentrations by Laser Ablation ICP-MS in subcalcic garnets from Saskatchewan and Somerset Island, Canada.	361
Jacob, D.E., Matthey, D.P.	Geochemistry of layered kyanite-bearing eclogites from the Roberts Victor Mine, South Africa.	364
James, D.E., van der Lee, S., Gao, S., Silver, P., VanDecar, J., Kuehnel, R., Jordan, T.H., Saltzer, R., Gaherty, J., Gore, J., Zengeni, T., Nguiri, T., Wright, C., Webb, S., Burford, D., Doucoure, M., Molisana, M., Green, R., Robey, J., Harvey, J., Kostlin, E., Reichardt, F.	Review of Seismic Structure of the Continental Lithosphere with Results from the Southern Africa Seismic Experiment	366
Janney, P.E., le Roex, A.P.	Causes of Compositional Diversity in the Olivine Melilitites of Namaqualand-Bushmanland, South Africa.	371
Janney, P.E., le Roex, A.P., Viljoen, K.S.	Trace Element and Isotopic Characteristics of Olivine Melilitites from the Western Cape, South Africa: Implications for the Sources of Group 1 Kimberlites.	374
Janse, A.J.A.	Archons, Protons and Tectons: an update.	377
Johnson, L.H., Burgess, R., Turner, G., Milledge, H.J.	Fluids trapped within diamond: clues to mantle geochemistry.	380
Johnson, L.H., Burgess, R., Turner, G., Milledge, H.J.	Noble gas and halogen systematics of fluids within diamond coats from Canada and Africa.	383
Jones, A.P., Dobson, D., Milledge, H.J., Taniguchi, T., Litvin, Y., Genge, M.J., Rabe, R.	Experiments with low-T potassic carbonatitic melts, fluids and diamonds.	386
Kaminsky, F.V., Gorzynsky, G., Sablukova, L.I., Sablukov, S.M., Zakharchenko, O.D.	Primary Sources of Diamonds in the Birim Area, Ghana.	389
Kaminsky, F.V., Sablukov, S.M., Sablukova, L.I., Shpanov, V.E., Zhuravlev, D.Z.	Diamondiferous Minette Dykes from the Parker Lake Area, N.W.T., Canada.	392
Kaminsky, F.V., Zakharchenko, O.D., Channer, D.M., DeR., Blinova, G.K., Maltsev, K.A.	Diamonds from the Guaniamo area, Venezuela.	395
Kelemen, P.B.	One view on the genesis of cratonic mantle peridotites.	398
Keller, R.A., Remley, D.A., Snyder, G.A., Taylor, L.A., Sobolev, N.V.	Mantle Xenoliths from the Obnazhennaya Kimberlite, Yakutia.	402
Keller, R.A., Taylor, L.A., Snyder, G.A., Sobolev, V.S., Carlson, W.D., Sobolev, N.V., Pokhilenko, N.P.	3-D Petrography of a Diamondiferous Eclogite from Udachnaya, Siberia.	405
Kempton, P.D., Hawkesworth, C.J., Lopez-Escobar, L., Ware, A.J.	Geochemistry of spinel ± garnet lherzolite xenoliths from Pali Aike: implications for evolution of mantle lithosphere beneath southern Patagonia	408
Kent, R.W., Paul, D.K., Basu, A., Ghose, N.C., Kempton, P.D.	Mafic alkaline intrusions in the Damodar Valley, India: the micaceous kimberlite - lamproite connection revisited.	411
Kepezhinskias, K., Kepezhinskias, P.	Ultramafic - Mafic rocks of the Eastern European Craton and Their Diamond Potential.	414
Kepezhinskias, P., Defant, M.J., Maury, R., Clague, A., Joron, J., Cotten, J., Kilty, S.J.	Composition of Island-Arc Mantle and its Bearing on the Origin of Cratonic Lithosphere.	417
Kinny, P.J., Trautman, R.L., Griffin, B.J., Harte, B.	Airborne Electromagnetic and Magnetic Surveying in the Search for Kimberlites.	420
Kinzler, H.J., Grove, T.L.	Carbon isotopic analyses of microdiamonds.	423
	Origin of Depleted Cratonic Harzburgite by Deep Fractional Melt Extraction and Shallow Olivine Cumulate Infusion.	426

Kirkley, M.B., Kolebaba, M.R., Carlson, J.A., Gonzales, A.M., Dyck, D.R., Dierker, C., Kiviets, G., Phillips, D., Shee, S.R., Vercoe, S.C., Barton, E.S., Smith, C.B., Fourie, L.F., Kjarsgaard, B.	Kimberlite Emplacement Processes Interpreted from Lac de Gras Examples. 40Ar/39Ar Dating of yimengite from the Turkey Wall kimberlite, Australia: The oldest and the rarest. Compositional trends of spinel and mica in alkali minettes, southern Alberta, Canada.	429 432 435
Klemme, S., O'Neill, H.St.C.	The partitioning of Chromium between orthopyroxene and spinel in the system MgO-Al ₂ O ₃ -SiO ₂ -Cr ₂ O ₃ : implications for geothermobarometry for Upper Mantle rocks.	438
Klump, J., Gurney, J.J.	A Pilot Study of the Swartuggens Kimberlite Dyke Swarm.	441
Koga, K.T., Shimizu, N., Grove, T.L.	Disequilibrium trace element re-distribution during garnet to spinel facies transformation.	443
Kong, J.M., Boucher, D.R., Scott-Smith, B.H.	Exploration and Geology of the Attawapiskat kimberlites, James Bay Lowland, Northern Ontario, Canada.	446
Kopylova, M.G., Russell, J.K., Cookenboo, H.	Petrography and Chemistry of the Jericho kimberlite (Slave Craton, Northern Canada).	449
Kopylova, M.G., Russell, J.K., Cookenboo, H.	Upper mantle stratigraphy and thermal regime of the north central Slave Craton, Canada.	452
Kopylova, M.G., Russell, J.K., Cookenboo, H.	Unique chemical features of the peridotitic mantle below the Jericho kimberlite (Slave Craton, Northern Canada).	455
Kornilova, V.P., Safronov, A.F., Philipov, N.D., Zayzev, A.I.	The garnet of diamond association in lamprophires from the Anabar massif.	458
Kostrovitsky, S.I., Pavlova, L.A., Suvorova, L.V.	Preliminary information about the first finding of Ti-bearing kirschsteinite (Fe-monticellite) in kimberlites.	460
Kostrovitsky, S.I., de Bruin, D.	Ultramafic association of minerals (garnet-ureyite diopside-chromspinelid) in micaous kimberlites of Yakutian province.	463
Kostrovitsky, S.I., Morikiyo, T.	Sr,Nd isotopic data of kimberlites and related rocks from North of Yakutian kimberlite province (Russia).	466
Kouznetsova, E.I., Gaidin, N.E.	Continental lithosphere deep structure researches on the base of scientific deep drilling	469
Kravchenko, S.M.	Kimberlite Types IA, IB, and II as Series from Different Mantle Depths.	471
Kryvoslyk, I.N.	Brief Review of the Theory of Liquid Immiscibility of Kimberlite Magma.	473
Kuehner, S.M., Irving, A.J.	Corundum-kyanite Eclogite, Grospydite and Epidote Amphibolite of Probable Subducted Slab Origin from Paleogene Diamondiferous Pipes in SW Wyoming	475
Kukkonen, I.T., Peltonen, P.	Geotherm and a rheological profile for the central Fennoscandian lithosphere.	478
Kullgin, S.S., Pokhilenko, N.P.	Mineralogy of xenoliths of garnet pyroxenites from kimberlite pipes of Siberian Platform.	480
Kurszlaukis, S., Lorenz, V., Zimanowski, B., Büttner, R.	Experiments on explosive interaction of molten kimberlite with injected water.	483
LeCheminant, A.N., Heaman, L.M., Kretschmar, U., LeCouteur, P.C.	Complex Origins and Multiple Ages of Mantle Zircon Megacrysts from Canadian and South African Kimberlites.	486
Lee, C.T.	Are inflected geotherms real?	489
Lee, C.T., Rudnick, R.L.	The origin and demise of cratonic lithosphere: a geochemical perspective from the Tanzanian craton.	492
Leggatt, P.B., Klinkert, P.S.	The application of Airborne Electromagnetic methods in the search for buried Kimberlites and Diamondiferous Gravels.	495
Leluyh, M.I., Kostrovitsky, S.I., Bezborodov, S.M., Nikulin, V.I., Prokopen, S.A., Serov, V.P., Tolstov, A.V., Zuev, V.M.	Kimberlites and related rocks of Anabar region (Yakutia, Russia).	497
Latendre, J., McCandless, T.E., Eastoe, C.J.	Morphology and Carbon Isotope Composition of Microdiamonds from Dachine, French Guiana.	500
Litasov, K.D., Kostrovitsky, S.I., Litasov, Yu.D.	Comparison of ilmenite-clinopyroxene symplectites from Vitim alkaline basalts and Yakutian kimberlites (Siberia, Russia).	503
Litasov, K.D., Litasov, Yu.D.	Reactional and differentiated pyroxenite xenoliths from alkaline basalts of the Vitim volcanic field (East Siberia): their role in metasomatism and position in mantle magmatic system.	506
Litasov, Yu.D., Niida, K., Litasov, K.D.	Reactional modification of the primitive mantle by basaltic melts: an evidence from mantle-derived xenoliths of the Vitim Plateau (Russia).	509
Logvinova, A.M., Fedorova, E.N., Sobolev, N.V.	Microdiamonds from the Yubileynaya kimberlite pipe, Yakutia: morphology, physical properties, and mineral inclusions	512
Luk'yanova, L.I., Lobkova, L.P., Zhukov, V.V., Rybal'chenko, A.Y., Ostroumov, V.P.	Diamonds of the Urals Mobile Belt and Source Rocks for the Uralian (Brazilian) type Diamond Placers.	515
Lütjen, H., Blume, J., Pretorius, C.C.	Geophysical survey over the Elizabeth Bay Mine, Namibia.	518
Mabuza, M., Viljoen, K.S., Majola, S.	New diamond-bearing xenoliths from the Orapa Mine, Botswana.	521
Machin, K.J., Barton E.S.	The petrology of the Rex Mine kimberlite fissures, central Free State, South Africa.	524
Magee, C.W., Taylor, W.R.	Constraints on the history and origin of carbonado from luminescence studies.	527
Mahotkin, I.L.	Petrology of Group 2 Kimberlite - Olivine lamproite (K2L) from the Kostomuksha area, Karelia, N.W. Russia.	529
Mahotkin, I.L., Skinner, E.M.W.	Kimberlites from the Archangelsk region - A rock type transitional between kimberlites, melnoites and lamproites.	532
Mainprice, D., Barruol, G., Ben Ismail, W., Lloyd, G.	Automatic crystal orientation mapping of Kimberlite nodules using electron back scattered diffraction in the scanning electron microscope.	535

	Title	Page No's
Mal'kov, B.A.	The Cosmic Cycles of Kimberlite Volcanism: New Data.	537
Mal'kov, B.A., Malyshev, N.A.	Diamond Occurrences in Kimberlites and Lamproites from Phanerozoic Mobile Belts on Example of the Timans, Urals and Ouachita.	540
Malkovets, V.G., Ionov, D.A., Griffin, W.L., O'Reilly, S.Y., Pokhilenko, N.P., Litasov, K.D.	A-P-T-composition cross-section of spinel and garnet facies lithospheric mantle in the Minusa region SW of the Siberian craton.	543
Marakushev, A.A., Bobrov, A.V.	Crystallization of Eclogite and Pyroxenite Magmas in the Diamond Depth Facies: Evidence from Garnet-Clinopyroxene Association.	546
Mason, P.R.D., Downes, H., Jarvis, K., Vannucci, R.	An investigation of incompatible trace elements in Massif Central mantle xenoliths by laser ablation ICP-MS: a new tool for investigating mantle geochemistry.	549
Massonne, H.J.	A new occurrence of microdiamonds in quartzofeldspathic rocks of the Saxonian Erzgebirge, Germany, and their metamorphic evolution.	552
McCammon, C.A.	Methods for Determination of Fe ³⁺ /ΣFe in Microscopic Samples.	555
McCandless, T.E.	Kimberlites: the Products of Deep-Seated Subduction.	558
Mc Dade, P., Harris, J.W.	Syngenetic inclusion bearing diamonds from Letseng-la-Terai, Lesotho.	561
McKinlay, F.T., Scott Smith, B.H., de Gasparis, S., Kong, J.	Geology of the Recently Discovered Hardy Lake Kimberlites, NWT	564
Mendelssohn, M., Milledge, H.J.	Characterisation of diamonds by infrared spectroscopy.	567
Menzies, A.H., Baumgartner, M.C.	Application of garnet geothermobarometry to southern African kimberlites.	570
Menzies, A.H., Gurney, J.J., Harte, B., Hauri, E.	REE patterns in diamond bearing eclogites and diamond bearing peridotites from Newlands Kimberlite	573
Menzies, A.H., Milledge, H.J.M., Gurney, J.J.	Fourier Transform Infra-red (FTIR) Spectroscopy of Newlands diamonds	576
Menzies, A.H., Shirey, S.B., Carlson, R.W., Gurney, J.J.	Re-Os isotope systematics of diamond-bearing eclogites and peridotites from Newlands Kimberlite	579
Mikhailov, M.V., Kuznetsova, M.Yu., Kuzmina, T.S., Polyakov, A.A., Lukyanova, L.I.	New data on potential diamond presence in Western Russia.	582
Milashchev, V.A.	Energy of kimberlite formation.	584
Milledge, H.J., Sutherland, F.L., Kennewell, P.	Further studies of Copeton Diamonds.	587
Milledge, H.J., Woods, P.A., Beard, A.D., Shelkov, D., Willis, B.	Cathodoluminescence of polished carbonado.	589
Miller, A.R., Seller, M.H., Armitage, A.E., Davis, W.J., Barnett, R.L.	Late Triassic kimberlitic magmatism, western Churchill Structural Province, Canada.	591
Milshtein, E.D., Ennchek, Yu.M., Egorin, A.V., Parasotka, B.S.	The structure of the Lithosphere in Diamond-Bearing Kimberlite Areas. The Siberian Platform.	594
Mironov, V.P.	Internal Morphology of Diamonds from Pipe Udachnaya According to the Data of Luminescence Tomography Method.	597
Mitchell, R.H., Scott Smith, B.H., Larsen, L.M.	Mineralogy of Ultramafic Dikes from the Sarfartoq, Sisimiut and Maniitsoq areas, west Greenland: Kimberlites or Melnoites?	600
Mitioukhine, S.I.	Chief Feature of Rocks of the Earth's crust within Kimberlite Provinces - Moderation of their Petrochemical Indicators.	603
Mitioukhine, S.I., Manakov, A.V., Poltaratskaya, O.L., Romanov, N.N.	New Data about the Structure of the Earth's crust according to Regional Geophysical Investigations' Results within Yakutian Kimberlitic Subprovince.	606
Moser, D.E., Hart, R.J.	Neoproterozoic and Paleoproterozoic re-activation of the crust-mantle transition beneath the central Kaapvaal craton, Lacey kimberlite.	609
Nassichuk, W.W., Dyck, D.R.	Fossils Recovered from Kimberlite Pipes in the Lac de Gras Field, Slave Province, Northwest Canada; Geological Implications.	612
Natapov, L., Griffin, W.L.	Geodynamic controls on the distribution of diamondiferous kimberlites.	615
Navon, O.	Diamond formation in the Earth's mantle	618
Nguno Muatara, A.	Indicator minerals in kimberlites and their respective stream sediments, Gibeon Kimberlite Province, Namibia.	622
Nixon, P.H., Pearson, D.G.	Ultra-magnesian komatites of phanerozoic age, from SE Spain.	625
Nowell, G.M., Kempton, P.D., Pearson, D.G.	Hf-Nd Isotope Systematics of Kimberlites: Relevance to Terrestrial Hf-Nd systematics.	628
Nowell, G.M., Kempton, P.D., Pearson, D.G.	Trace Element and isotope Geochemistry of Siberian Kimberlites.	631
Nowell, G.M., Pearson, D.G.	Hf Isotope Constraints on the Genesis of Kimberlitic Megacrysts: Evidence for a Deep Mantle Component in Kimberlites.	634
Nowell, G.M., Pearson, D.G., Kempton, P.D., Irving, A.J., Turner, S.	A Hf isotope Study of Lamproites: Implications for their Origins and Relationship to Kimberlites	637
Nowell, G.M., Pearson, D.G., Kempton, P.D., Noble, S.R., Smith, C.B.	The source regions/components of kimberlites: Constraints from Hf-Nd isotope systematics.	640
O'Brien, H.E., Tyni, M.	Mineralogy and geochemistry of Kimberlites and related rocks from Finland.	643
O'Reilly, S.Y., Griffin, W.L., Poudjorn Djomani, Y.	Are Lithospheres forever?	646
Pal'yanov, Yu.N., Gusev, V.A., Kupriyanov, I.N., Borzdov, Yu.M., Sokol, A.G., Khokhriakov, A.F., Sobolev, N.V.	The effect of growth rate on formation of nitrogenous defects in diamond.	649
Panina, L.I.	Genesis of Cocites from North Vietnam: Results of Melt Inclusions Studies in Minerals.	652
Panina, L.I., Usoltseva, L.M.	The Role of High-Calcium Alkaline Sulfate-Carbonate Melts in Formation of Melilitite-Monticellite Rocks and Carbonatites of the Maiyi Murun Massif (Aldan, Russia).	655

Pearson, D., Carlson, R.W., Boyd, F.R., Shirey, S.B., Nixon, P.H.	Lithospheric mantle growth around cratons: A Re-Os isotope study of peridotite xenoliths from East Griqualand.	658
Pearson, D.G., Shirey, S.B., Bulanova, G.P., Carlson, R.W., Milledge, H.J.	Dating diamonds using the Re - Os isotope technique: A study of sulfide inclusions in Siberian diamonds.	661
Pearson, D.G., Davies, R.M., Shirey, S. B., Carlson, R.W., Griffin, W.L.	The age and origin of eastern Australian diamonds: Re-Os isotope evidence from sulfide inclusions in two diamonds from Wellington, New South Wales.	664
Pearson, D.G., Milledge, H.J.	Diamond growth conditions and preservation: Inferences from trace elements in a large garnet inclusion in a Siberian diamond.	667
Pearson, N.J., Griffin, W.L., Doyle, B.J., O'Reilly, S.Y., van Achterbergh, E., Kivi, K.	Xenoliths from kimberlite pipes of the Lac de Gras area, Slave Craton, Canada.	670
Pearson, N.J., Griffin, W.L., Kaminsky F.Y., van Achterbergh, E., O'Reilly, S.Y.	Trace element discrimination of garnet from diamondiferous kimberlites and lamproites.	673
Peltonen, P.	Silicification of Garnet Peridotite Xenoliths from the Lahtojoki Kimberlite Pipe, Eastern Finland.	676
Peltonen, P., Huhma, H., Tyni, M., Shimizu, N.	Garnet Peridotite Xenoliths from Kimberlites of Finland: Nature of the Lithospheric Mantle at Archaean craton - Palaeoproterozoic mobile belt transition.	678
Pendock, N.	Breaking the Nyquist Barrier: Superresolution Magnetic Imaging from Gradient Data.	681
Pereira, R.S., Wheelock, G., Bizzli, L., Silva, H., Leite, A.	Alluvial diamond potential of Paleo-Drainage systems in the Headwaters of the Sao Francisco River, Minas Gerais, Brazil	684
Phillips, D., Hamis, J.W., Kiviets, G.B., Burgess, R., Fourie, L.F.	40Ar/39Ar Laser Probe Analyses of Clinopyroxene Diamond Inclusions from the Orapa and Mbuyi-Miya Mines.	687
Phillips, D., Kiviets, G.B., Barton, E.S., Smith, C.B., Viljoen, K.S., Fourie, L.F.	40Ar/39Ar Dating of Kimberlites and Related Rocks: Problems and Solutions.	690
Pizzolato, L.A., Schulza, D.J.	Preliminary investigations of megacrysts and peridotite xenoliths from the Kelsey Lake kimberlite, Colorado-Wyoming, USA.	693
Podvysotsky, V.T., Zuev, V.M., Nikuln, V.I., Lelyoukh, M.I., Bezborodov, S.M.	Conception of Formation of Magmatogene and Terrigenous Diamondiferous Formations of Ancient Platforms as the basis of deposits' forecast.	696
Pokhilenko, N.P., McDonald, J.A., Melnyk, W., Hall, A.E., Shimizu, N., Vavilov, M.A., Afanasiev V.P., Reimers, L.F., Irvin, J., Pokhilenko, L.N., Vasilenko, V.B., Kuligin, S.S., Sobolev, N.V.	Kimberlites of Camsell Lake field and some features of construction, and composition of lithosphere roots of southeastern part of Slave Craton, Canada.	699
Pokhilenko, N.P., Sobolev, N.V., Kuligin, S.S., Shimizu, N.	Peculiarities of pyroxenite paragenesis garnets distribution in Yakutian kimberlites and some aspects of the Siberian craton lithospheric mantle evolution.	702
Presnall, D.C., Walter, M.J.	High pressure phase equilibrium constraints on the origin of eclogites.	705
Pretorius, C.C., Blume, J., Lütjen, H., Trofimczyk, K.	Results of Geophysical trials to profile the Kimberlite/Host rock contacts at Venetia Mine and the BK-9 Pipe.	708
Pretorius, W., Barton, J.M., Jr.	The Use of Amphibolite Melting Experiments in Constraining Conditions of Melting in Natural Amphibolite Nodules from the Venetia Kimberlite Pipes.	710
Pretorius, W., Leahy, K.	Implications for diamond prospectivity from comparisons of diamond-bearing lithosphere in two Proterozoic orogenic belts.	713
Prikhodko, V.S., Zemlyanukhin, V.N.	Petrology of spinel Peridotite Xenoliths from Cenozoic Basaltoids in the Khanka Craton's Terrain (East Russia)	716
Pybus, G.Q.J., Hussey, M.C., Linton, P.L.	Spectral investigations of a variety of magnesium-bearing rock types: Implications for kimberlite exploration.	717
Rapp, R.P., Shimizu, N.	Subduction and Slab Melting in the Archean: Experimental Constraints and Implications for Development of Cratonic Lithosphere.	720
Rass, I.T., Gerasimov, V.Yu., Laputina, I.P., Ilupin, I.P.	Diamond occurrence in kimberlites dependent on melting depths and rates of cooling of parental mantle magmas.	723
Rass, I.T., Kravchenko, S.M.	Mellilite-Bearing Rocks within Alkaline-Ultrabasic Complexes: Derivatives from SiO ₂ -Poor, Ca-Rich Mantle Magma?	725
Reid D.L., Cooper A. F.	Carbonatite and silicate magmas at Dicker Willem, southern Namibia : their origin and source region characteristics	727
Reimers, L.F., Pokhilenko, N.P., Yefimova, E.S., Sobolev, N.V.	Ultramafic mantle assemblages from Sytykanskaya kimberlite pipe (Yakutia).	730
Rice, A.	Can the blasting excavation engineering sciences provide insight into the processes of kimberlite emplacement and eruption?	733
Richardson, S.H., Chinn, I.L., Harris, J.W.	Age and Origin of Eclogitic Diamonds from the Jwaneng Kimberlite, Botswana.	734
Robinson, D.N., Ferraris, R., Anderson, V.G., Parker, G.M., Van Blerck, E., Hart, D.	Colour, Morphological and Surface Textural Characteristics of the Diamonds in Venetia Kimberlites.	737
Roden, M.F., Laz'ko, E.E., Jagoutz, E.	Petrology and Geochemistry of Peridotite Inclusions from the Mir kimberlite, Siberia	740
Rodionov, A.S., Viljoen, K.S.	Venetia megacrysts, Northern Province, South Africa.	743
Romashkin, A.I.	Potassium Alkaline Magmatism in the Russian Far East.	746
Romashkin, A.I., Kukhtina, L.M.	Mineralogy of Ingilite.	749
Rombouts, L.	Extreme Value Analysis of Diamond Sizes and Values.	752
Rudnick, R.L., Ireland, T.R., Gehrts, G., Irving, A.J., Chesley, J.T., Hanchar, J.M.	Dating Mantle Metasomatism: U-Pb Geochronology of zircons in cratonic mantle xenoliths from Montana and Tanzania.	754
Ruiz, J., McCandless, T.E., Helmstaedt, H.H.	Eclogites from the Colorado Plateau: A Phanerozoic Record of Subduction beneath North America.	757

Satykov, O.G., Erinchek, Yu.M., Milshtein, E.D	The model of buried kimberlite field based on its reflection in postkimberlite reservoir rocks (by the example of the Yakutian province).	760
Saparn, G.V., Obyden, S.K., Titkov, S.V	Use of Cathodoluminescence Scanning Electron Microscope with Color TV Display for Study of Natural Diamonds Internal Structure.	763
Schmitz, M.D., Bowring, S.A., Robey, J.v.A.	Constraining the thermal history of an Archean craton: U-Pb thermochronology of lower crustal xenoliths from the Kaapvaal craton, southern Africa	766
Schulze, D.J., Valley, J.W., Bell, D.R., Spicuzza, M.	Significance of Oxygen Isotope Variations in the Cr-Poor Megacryst Suite.	769
Scott Smith, B.H., Orr, R.G., Robertshaw, P., Avery, R.W.	Geology of the Fort A La Come Kimberlites, Saskatchewan.	772
Seggie, A.G., Hannweg, G.W., Colgan, E.A., Smith, C.B.	The Geology and Geochemistry of the Venetia Kimberlite cluster, Northern Province, South Africa.	775
Seitz, H.M., Woodland, A.B	Lithium and Beryllium abundances in peridotitic, pyroxenitic and eclogitic mantle assemblages.	778
Selfe, G.R., Trofimczyk, K.K.	Recent developments in the application of Borehole Geophysical logging techniques in Diamond Mining and exploration - some case studies.	781
Shamshina, E.A., Zaitsev, A.I.	New age of Yakutian kimberlites.	783
Sharygin, V.V	Melt inclusions and Chromite in Lamproites from Smoky Butte, Montana.	785
Sharygin, V.V., Golovin, A.V., Smirnov, S.Z., Malkovets, V.G	Relationship between Websterite Xenolith and Host Basanite (Pipe Bele, Khakasia, Russia): Evidence from Fluid and Silicate-Melt Inclusions in Minerals.	788
Sharygin, V.V., Litasov, K.D., Smirnov, S.Z., Kuzmin, D.V., Reutsky, V.N., Ivanov, A.V	Fluid and Silicate-Melt Inclusions and Interstitial Glass in Mantle Xenoliths from Melanephelinites of the Udokan Lava Plateau, Russia.	791
Sharygin, V.V., Pospelova, L.N	Sulphide inclusions in Early Lamproite Minerals.	794
Shatsky, V.S., Zedgenizov, D.A., Yefimova, E.S., Rylow, G.M., De Corte, K., Sobolev, N.V.	A comparison of morphology and physical properties of microdiamonds from the mantle and crustal environments.	797
Shee, S.R., Vercoe, S.C., Wyatt, B.A., Campbell, A.N., Colgan, E.A., Hwang, P.H.	Discovery and Geology of the Nabberu Kimberlite Province, Western Australia.	800
Shimizu, N., Pokhilenko, N.P., Boyd, F.R., Pearson, D.G	Trace element characteristics of garnet dunites/harzburgites, host rocks for Siberian peridotitic diamonds.	803
Shimizu, N., Pokhilenko, N.P., McDonald, J.A	Geochemical characteristics of the Slave craton lithosphere: A view from heavy mineral concentrate garnets.	805
Shimizu, N., Sobolev, N.V., Yefimova, E.S.	Trace element heterogeneities in-situ diamond inclusion garnets from Siberia	807
Shirey, S.B., Carlson, R.W., Gurney, J.J., van Heerden, L.	Re-Os Isotope Systematics of Eclogites from Roberts Victor: Implications for Diamond Growth and Archean Tectonic Processes.	808
Shiryayev, A.A., Galimov, E.M., Sobolev, N.V., Kolesov, G.M., Zakharchenko, O.D.	Trace Elements in Inclusion-free Diamonds from Venezuela and Arkhangelsk Deposits.	811
Simakov, S.K.	Garnet - clinopyroxene geobarometry of deep mantle eclogites and eclogite paleogeotherm	814
Skinner, E.M.W., Mahotkin, I.L., Grütter, H.S	"Melilite" in Kimberlites.	817
Smith, S.C., Ihinger, P.D.	Geochemical evolution of the New England lamprophyre suite: a hotspot signature preserved in the continental crust?	820
Snyder, G.A., Keller, R.A., Taylor, L.A., Remley, D., Halliday, A.N., Sobolev, N	The Origin of Ultramafic (Group A) Eclogites: Nd & Sr Isotopic Evidence From the Obnazhennaya Kimberlite, Yakutia.	823
Snyder, G.A., Taylor, L.A., Beard, B.L., Halliday, A.N., Sobolev, N.V	The Diamond-Bearing Mir Eclogites, Yakutia: Nd And Sr Isotopic Evidence for Continental Crustal Input In An Archean Oceanic Environment.	826
Sobolev, N.V., Yefimova, E.S., Channer, D., Anderson, P.F.N., Barron, K.M	A unique eclogitic source of Guaniamo diamonds, Guyana shield, Venezuela.	829
Sobolev, N.V., Yefimova, E.S., Koptil, V.I	Crystalline inclusions in Diamonds in the Northeast of the Yakutian Diamondiferous Province.	832
Sobolev, V.N., Taylor, L.A., Snyder, G.A., Jerde, E.A., Neal, C.A., Sobolev, N.V	Metasomatism of the Mantle Beneath Yakutia: A Quantitative Study of Secondary Chemistry and Mineralogy in Udachnaya Eclogites.	835
Sokolovsky, A.K., Serokurov, Yu.N., Kalmykov, V.D	System analysis of remote sensing data on structural control of diamondiferous areas	838
Solovjeva, L.V., Barankevich, V.G., Bayukov, O.A., Glazunov, O.M	Polychrome olivines in coarse grained herzolites from the Udachnaya pipe - possible fine indicators of reduced metasomatism	841
Spetsius, Z.V	Two Generations of Diamonds in the Eclogite Xenoliths.	844
Spetsius, Z.V., Bezborodov, S.M	Compositional variations and floatability of Kimberlite Ores of Russia	847
Spetsius, Z.V., Griffin, B.J	Secondary phases associated around diamonds in eclogites from the Udachnaya kimberlite pipe: Implications for diamond genesis.	850
Spetsius, Z.V., Griffin, W.L	Trace element composition of garnet kelyphites in xenoliths from Udachnaya as evidence of their origin.	853
Spetsius, Z.V., Taylor, W.R., Griffin, B.J.	Major and trace element partitioning between mineral phases in diamondiferous and non-diamondiferous eclogites from the Udachnaya kimberlite pipe, Yakutia.	856
Stachel, T., Harris, J.W., Brey, G.P	Inclusions in diamonds from Mwadui (Tanzania) - chemical mush in the source.	859
Stachel, T., Viljoen, K.S., Harris, J.W., Brey, G.P	REE patterns of garnets from diamonds and diamondiferous peridotites - geochemical signatures of the diamond source.	862
Stasiuk, L.D., Lockhart, G.D., Nassichuck, W.W., Carlson, J.A., Tomica, M.	Kimberlite emplacement temperatures derived from the thermal history of Organic matter, Lac de Gras, Canada.	865

R., Hannweg, G.W. St Pierre, M., Wynne, P.J., Counts, B.	The petrology of a mantle xenolith suite from Venetia, South Africa.	868
Sweeney, R.J., Konzett, J., Prozesky, V.M.	Paleomagnetisation of Kimberlites on the BHP/Dia Met Diamond Project.	871
Sweeney, R.J., Winter, F.	The determination of hydrogen in peridotitic minerals by nuclear methods.	874
Tainton, K.M., Seggie, A., Bayly, B.A., Tomlinson, I., Quadling, K.E.	Kimberlite as high-pressure melts: the determination of segregation depth from major element chemistry.	877
Taylor, L.A., Bulanova, G.P., Snyder, G.A., Keller, R.A.	Regional variation in mantle heat flow within the Tanzanian Craton.	880
Taylor, W.R., Bristow, J.	Multiple Inclusions In Diamonds: Evidence For Complex Petrogenesis.	883
Taylor, W.R., Jaques, A.L.	Cyclicality of Continental Alkaline Magmatism in the Geological Record.	886
Taylor, W.R., Kamperman, M., Hamilton, R.	Crystallization history of the Argyle and Ellendale olivine lamproites: constraints from spinel-olivine thermometry and oxygen barometry.	888
Taylor, W.R., Kingdom, L.	New thermometer and oxygen fugacity sensor calibrations for ilmenite- and chromian spinel-bearing peridotitic assemblages.	891
Taylor, W.R., Matveev, S.	Mineralogy of the Jagersfontein kimberlite - an unusual Group I micaceous kimberlite - and a comment on the robustness of the mineralogical definition of 'orangeite'.	892
Taylor, W.R., Nimis, P.	Recalibration of the 5-parameter MRK equation of state for C-O-H fluids under upper mantle conditions and some experimental tests.	895
Taylor, W.R., Reddcliffe, T.H., Jakimowicz, J.	A single-pyroxene thermometer for hercynitic Cr-diopside and its application in diamond exploration.	897
Teixeira, N.A., Gaspar, J.C., Oliveira, A.L.A.M., Bitencourt, R.M., Yeda, B.	Thermobarometry of peridotitic Cr-diopside from the Merlin kimberlites, Northern Territory, Australia - nature of the upper mantle beneath the Proterozoic North Australian craton.	899
Teixeira, N.A., Gaspar, J.C., Weissel, O., Almeida, A.J., Belther, J.A., Gobbo, L.	Morphology of the Juina Maars	902
Thomas, R.D., Novak, N.A., Janse, A.J.A.	Geology of the Juina Diamondiferous Province	905
Titkov, S.V., Bershov, L.V., Scandale, E., Saporin, G.V., Chukichev, M.V., Speranskiy, A.V.	Diamonds in ultrabasic rock near Wawa, Ontario, Canada.	908
Titkov, S.V., Gorshkov, A.I., Vinokurov, S.F., Bershov, L.V., Solodov, D.I., Sivtsov, A.V.	Nickel Structural Impurities In Natural Diamonds.	911
Tompkins, L.A., Meyer, S.P., Han, Z., Hu, S.	Carbonado from Yakutian diamond deposits (Russia): microinclusions, impurities, and paramagnetic centers.	914
Tompkins, L.A., Taylor, W.R., Ramsay, R.R., Armstrong, R.	Petrology and Geochemistry of Kimberlites from Liaoning and Shandong Provinces, China.	917
Tomshin, M.D., Fomin, A.S., Oleinikov, B.V.	The Mineralogy and Geochemistry of the Kamafugitic Tres Barras Intrusion, Mata da Corda, Minas Gerais, Brazil.	920
Trautman, R.L., Griffin, B.J., Bulanova, G.P.	Basites of the Vilyui - Markha zone (Siberian platform).	923
Tsyganov, V.A., Kontarovich, R.S.	Growth features and nitrogen aggregation properties of microdiamonds derived from kimberlite diatremes.	926
Ulmer, G.C., Grandstaff, D.E., Göbbels, M., Woermann, E.	Target-specific airborne geophysical forecast-exploration technology for diamond deposits <Field - Cluster - Pipe>.	929
Van Achterbergh, E., Griffin, W.L., Shee, S.R., Wyatt, B.A., Sharma, A.L.	An Experimental Delineation of the Oxygen Fugacity of Moissanite (SiC) bearing Silicate Systems	932
Van Achterbergh, E., Griffin, W., Stiefenhofer, J.	Natural Trace Element Distribution Coefficients for Garnet, Clino- and Orthopyroxene: Variations with Temperature and Pressure.	934
Verichev, E.M., Sablukov, S.M., Sablukova, L.I., Zhuravlev, D.Z.	Xenoliths from the Lethakane Kimberlite: Geochemistry and Implications for Mantle Processes.	937
Viljoen, K.S., Phillips, D., Harris, J.W., Robinson, D.N.	A new type of diamondiferous kimberlite of the Zimny Bereg area (pipe named after Vladimir Grib).	940
Vladykin, N.V., Lelyukh, M.I., Tolstov, A.V.	Mineral inclusions in diamonds from the Venetia kimberlites, Northern Province, South Africa.	943
Voinova, I.P., Prikhodko, V.S.	Lamproites of the Anabar region, Northern rimming of the Siberian platform.	946
Vouiko, V.	Post-accretionary stage in the evolution of ultramafic magmatism in accretionary prisms: rock types, diamond potential (on example of East Russia).	949
Ward, J.R., Norman, D.I.	Method of Quantitative Evaluation of Kimberlite Pipes' Productivity.	950
Williams, C.M., Robey, J.v A., Abson, J.P.	Geochemical and Physical Aspects of Diamonds from the Akwatia and Tarkwa Diamondfields in Southern Ghana, West Africa	953
Woermann, E., Göbbels, M., Ulmer, G.C., Grandstaff, D.E.	Petrography and Mineral Chemistry of the Mwenezi-01 Kimberlites, Zimbabwe.	955
Wood, B.D., Scott Smith, B.H., de Gasparis, S.	Moissanite and its bearing on the oxygen fugacity of the deeper regimes of the Earth's upper mantle	958
Woodland, A.B., Peltonen, P.	The Mountain Lake Kimberlitic Pipes of NW Alberta: Exploration, Geology and Emplacement Model.	960
Wyatt, B.A., Ma Wenyun, Li Ziyun, Joyce, J., Colgan, E.A., Smit, D., De Bels, M.	Ferric/Ferrous Iron Contents of Garnet and Clinopyroxene and Calculated Oxygen Fugacities of Peridotite Xenoliths from the Eastern Finland Kimberlite Province.	963
Wyatt, B.A., Morfi, L., Gurney, J.J., Pearson, N.J., Griffin, W.L.	The Ningxiang Lamproites, Hunan Province, China: Petrology and Mineral Chemistry.	965
	Garnets in a Polymict Xenolith from the Bultfontein Mine, South Africa: New Preliminary Geochemical and Textural Data.	968

	Title	Page No's
Wyatt, B.A., Sumpton, J.D.H., Shee, S.R., Smith, T.W	Kimberlites in The Forrest River Area, Kimberley Region, Western Australia.	971
Wyllie, P.J., Lee, W.J.	Kimberlites, carbonatites, peridotites and silicate-carbonate liquid immiscibility explained in parts of the system $\text{CaO}-(\text{Na}_2\text{O}+\text{K}_2\text{O})-(\text{MgO}+\text{FeO})-(\text{SiO}_2+\text{Al}_2\text{O}_3)-\text{CO}_2$	974
Yamashita, H., Arima, M., Ohtani, E.	Melting experiments of kimberlite compositions up to 9GPa: Determination of melt compositions using aggregates of diamond grains.	977
Yao, S., Griffin, W.L., O'Reilly, S.Y	Trace Elements in Chromites from Kimberlites and Related Rocks: Relation to Temperature and Mantle Composition.	980
Yaxley, G.M., Green, D.H.	Phase relations of carbonated eclogite under upper mantle PT conditions - implications for carbonatite petrogenesis.	983
Zack, T., Brumm, R	Ilmenite/liquid partition coefficients of 26 trace elements determined through ilmenite/cilnopyroxene partitioning in garnet pyroxenites.	986
Zartman, R.E., Richardson, S.H., Gurney, J.J., Moore, R.O.	U-Th-Pb Ages of Megacrystic Zircon from the Monastery Kimberlite, Free State, South Africa.	989
Zhang, A., Griffin, W.L., Ryan, C.G., Andrew, A	Conditions of Diamond Formation beneath the Sino-Korean Craton: Paragenesis, Temperatures and the Isotopic Composition of Carbon.	992
Zhang, Y	Mechanical equilibria in inclusion-host systems	995
Zhao, D., Essene, E.J., Zhang, Y., Pell, J.A	Mantle Xenoliths from the Nikos Kimberlites on Somerset Island, and the Zulu Kimberlites on Brodeur Peninsula, Baffin Island, Canada.	998
Zhao, L., Zhang, P., Huang, X., Li, Y	Deep Mantle Fluids and Their Products in Kimberlites from China.	1001
Zheng, J.	Phanerozoic Evolution of the Subcontinental Lithospheric Mantle, Eastern North China Block: Mantle Xenolith Evidence.	1004
Zichella, V., de Gasparis, A.A., Pendock, N.E.	Mineral mapping with hyperspectral data. A case study over the Moses Rock Dyke and Mule Ear Diatreme (UTAH, USA)	1007
Zintchouk, N	New Data about Crusts of Weathering on Kimberlites of Diamondiferous Territories.	1009
Zintchouk, N.N., Boris, Y.I	Erosional Section of Kimberlite Bodies and the Scales of Placer Diamondiferousness.	1013
Zintchouk, N.N., Boris, Y.I., Stegnitsky, Y.B	Specific Features of Kimberlite Prospecting in Various Landscape-geological Conditions.	1017
Zintchouk, N.N., Dukardt, Y.A., Boris, Y.I	Specific Features of Zoning of Ancient Platforms' Territories According to the Degree of Perspectiveness of Diamondiferous Kimberlites' Intrusion.	1020
Zintchouk, N.N., Koptil, V.I., Boris, Y.I	Ancient Platforms' Diamond Typomorphism (on the example of Siberian Platform).	1024
Zintchouk, N.N., Zuev, V.M., Mitioukhine, S.I	Regional Zoning of Territories According to the Level of Primary Diamond Sources' Diamondiferousness.	1028
Zuev, V.M., Bezborodov, S.M., Chyerny, S.D., Yanygin, Y.T., Molchanov, Y.D	The Structures which Control the Location of Kimberlites of Middle-Markhinsky Region.	1031
Zuev, V.M., Serokurov, Y.N., Kalmykov, V.D	Assessment of Diamondiferous Perspectives of East-European Platform according to the Data of Sounding from Space.	1034
Zweistra, P., Jarvis, W., McGeorge, I.B.	The Geology of Micaceous Kimberlite Intrusives, Khutse, Botswana.	1037