

- 📖 Introduction
- 📖 6 pages of tables analysis
- 📖 10 pages of textual discussion

Pemamon

Explor. Mining Geol., Vol. 6, No. 4, pp. 349-366, 1997
(D 1999 Canadian Institute of Mining, Metallurgy and Petroleum. Published by Elsevier Science Ltd.

0964-1823/97 \$17.00 +.00

P11: S0964-1823(98)00013-0

The Significance of Eclogite and Cr-poor Megacryst Garnets in Diamond Exploration

DANIEL J. SCHULZE

Department of Geology, University of Toronto
Erindale College
Mississauga, Ontario, Canada L5L 1C6

Received July 8, 1998; accepted February 1, 1999

Abstract—Eclogite is an important source of diamond in the upper mantle, but is more localized than peridotite. Using eclogitic minerals in kimberlite and diamond exploration is also more problematic than using the well-known peridotite-derived indicator minerals Cr-pyrope and magnesiochromite. The problems include color similarities between orange garnets from eclogites, Cr-poor megacrysts, and crustal garnets, chemical similarities with Cr-poor megacryst suite garnets (specifically elevated Na₂O contents), and low abundance of eclogite garnet xenocrysts in most known kimberlites. Chemical screens must be used carefully to distinguish between varieties of orange garnets in exploration samples. For example, most orange garnets of crustal origin have >22 wt% FeO, with mantle eclogite garnets having lower values. Na₂O-bearing garnets from the Cr-poor megacryst suite can be distinguished from Na₂O-bearing garnets from diamondiferous eclogites by the elevated TiO₂ contents of the former. The low abundance of eclogite garnet xenocrysts in kimberlites worldwide, however, may dictate that use of eclogite garnets in diamond exploration in most cases be restricted to advanced stages of kimberlite exploration and evaluation of kimberlite diamond potential. Cr-pyropes, Mg-ilmenites and Cr-rich chromites are more useful than eclogitic garnets in most stages of diamond exploration. If orange garnet xenocrysts are sought in a kimberlite exploration program, those from the Cr-poor megacryst suite will be more useful than eclogite derived garnets, due to the typical great abundance of the former, although they carry no information of the diamond potential of the host kimberlite. © 1999 Canadian Institute of Mining, Metallurgy and Petroleum. Published by Elsevier Science Ltd. All rights reserved.

Introduction

Worldwide, most diamonds in kimberlite and lamproite appear to be xenocrysts derived from upper mantle sources dominated by peridotite, typically harzburgite that contains small quantities of low-Ca Cr-pyrope and/or magnesiochromite, with subordinate contributions from garnet lherzolite (Gurney, 1989; Gurney et al., 1993; Gurney and Zweistra, 1995). This conclusion is based primarily on the abundance of minerals occurring as inclusions in diamonds, as diamond-bearing xenoliths are quite rare (Gurney, 1989). The only other important source of macrodiamonds is eclogite, and minerals of the eclogite suite are less commonly found included in diamonds, occurring in only one quarter of diamonds with inclusions examined from South Africa (Hawthorne et al., 1978; Gurney, 1984) and in a mere 1 % of inclusion-bearing Siberian diamonds (Yefirnova and Sobolev, 1977). Nevertheless, eclogite-suite diamonds appear to be dominant in some kimberlites and are locally of great economic significance, as several important diamond mines and well-known near-economic prospects have their diamond populations dominated by stones from the eclogite suite (e.g., Premier, Orapa, Letlhakane, Bellsbank and Monastery Mines in Africa, the sub-economic Sloan diatreme in the U.S.A. (all kimberlites) and the lamproite-

the absence of the eclogitic diamond component, in contrast to most economic kimberlites.

Although the indicator mineral approach to exploration for diamond-bearing kimberlites is reasonably well-understood and seems to work well for peridotite-dominated diamond suites (Gurney, 1984, 1989; Fipke et al., 1989, 1995; Gurney et al., 1993; Griffin and Ryan, 1995), the use of eclogite-derived indicator minerals in diamond exploration is not straightforward (Fipke et al., 1995; Nixon, 1995), and is hampered and confused by several factors. These include the low abundance of eclogitic garnet xenocrysts in most kimberlites and the color similarities between orange garnets from eclogites, Cr-poor megacrysts (Eggler et al., 1979), and many crustal metamorphic rocks. The constraints imposed by these, and other factors on the use of eclogite derived and Cr-poor megacryst-derived garnets in diamond exploration, are the focus of this paper.

In this paper, the compositions in the development of chemical screens useful in garnet classification. In addition, new mineral

and diamond grade data are presented for diamond-bearing eclogites from the Udachnaya Mine in Siberia (Tables 1 and 2), and mineral chemical data for Cr-poor garnet megacrysts from a variety of localities worldwide are shown in Table 3.

hosted Argyle Mine in Australia). Although peridotite-derived diamonds also occur at these localities, mining of the kimberlites mentioned above would not be feasible in

The data in Table 3 greatly expand the published data base for Cr-poor megacryst garnets, which are potentially of importance in kimberlite exploration.

Table 1. Compositions of garnets and clinopyroxenes from Udachnaya diamond eclogites

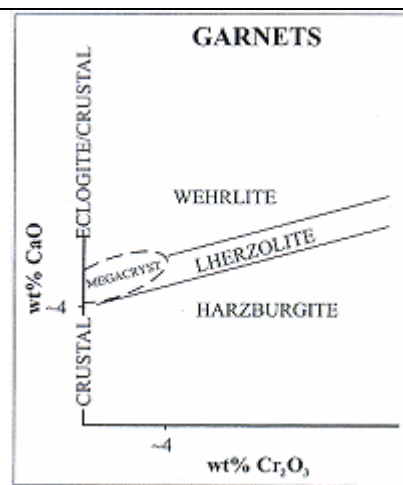
SiO2		T102	Al2O3	Cr2O3	FeW	MnO	Mgo	CaO	Na2O/K2O	Total	
UE-2*	ga	39.65	0.28	22.90	0.05	9.72	0.15	9.80	17.17	0.12	na1199.84
UE-4	ga	39.60	0.41	22.49	0.06	18.79	0.39	11.40	7.06	0.18	na100.38
	cpx	55.37	0.39	11.38	0.07	4.68	0.04	8.94	11.78	6.28	0.1499.09
UE-5**	ga	39.89	0.27	22.98	0.05	8.73	0.15	8.45	19.37	0.09	na99.98
	cpx	56.37	0.16	16.91	0.06	1.13	0.01	6.77	11.31	6.81	0.1399.71
UE-6*	ga	40.16	0.23	22.99	0.07	10.62	0.17	10.22	15.85	0.11	na100.42
UE-7	ga	39.87	0.28	22.64	0.05	18.81	0.37	13.51	4.45	0.14	na100.12
	cpx	55.01	0.42	10.32	0.04	6.02	0.10	9.67	11.31	6.07	0.1099.08
UE-9	ga	39.70	0.68	22.34	0.03	17.00	0.32	12.12	7.75	0.23	na100.17
	cpx	55.10	0.61	11.80	0.02	4.68	0.02	8.65	11.01	6.94	0.0598.90
UE-11	ga	41.28	0.65	22.91	0.03	11.63	0.38	17.83	4.86	0.18	na99.75
	cpx	54.93	0.42	9.42	0.11	5.23	0.08	10.89	12.11	5.74	0.3399.26
UE-13*	ga	40.02	0.24	22.97	0.04	11.31	0.17	9.71	15.57	0.11	na100.14
UE-14	ga	40.13	0.30	22.68	0.11	17.17	0.33	14.49	4.07	0.15	na99.43
	cpx	54.94	0.40	9.53	0.14	5.28	0.07	10.92	12.30	5.19	0.3299.09
UE-15	ga	39.89	0.66	22.40	0.05	16.36	0.36	12.67	7.10	0.23	na99.72
	cpx	55.01	0.55	11.59	0.06	4.31	0.04	9.05	11.43	7.11	0.0899.17
UE-17	ga	40.34	0.47	22.58	0.05	15.77	0.35	15.18	4.38	0.16	na99.28
	cpx	54.59	0.42	10.27	0.05	5.60	0.10	10.08	11.56	5.99	0.0698.74
UE-18	ga	39.90	0.32	22.62	0.04	18.41	0.38	12.62	5.51	0.16	na99.98
	cpx	55.10	0.47	10.85	0.07	4.56	0.06	9.57	10.85	6.08	0.3591%

+ all Fe reported as FeO; * corundum-bearing; ++ not analyzed; ** kyanite-bearing (grosopydite).

Table 2. Diamond grades of some diamond-bearing eclogites from Udachnaya

Sample	Grade (ct/tonne)
UE-2	16039
UE-4	11 082
UE-5	26028
UE-6	24814
UE-7	15029
UE-9	40 161
UE-11	101483
UE-13	9763
UE-14	5657
UE-15	27372
UE-17	30498
UE-18	37430
UE-19	22 116

Average (n= 13) 28267



Garnets in Kimberlite

Kimberlite magmas can incorporate xenoliths and xenocrysts from any rock type that they encounter in the crust and upper mantle on their rise to the surface. Upper mantle sources of garnet xenocrysts in kimberlite include peridotites (Iherzolites, harzburgites and wehrlites), eclogites and Cr-poor megacrysts. Garnets from crustal assemblages (e.g., schists, amphibolites and granulites) also occur in many kimberlites and constitute a significant proportion of the garnet xenocryst population in some kimberlites (Schulze, 1994). Figure 1 is a schematic representation of the compositions of these various garnet types in terms of their relative CaO and Cr2O3 values. What makes the peridotite, eclogite and Cr-poor megacryst garnets potential tracers of kimberlite is the fact that these indicators are indicating the presence of material derived from the upper mantle (the ultimate source of all macrodiamonds) included within the kimberlite. Some of this material is subsequently

Fig. 1. Schematic representation of CaO and Cr2O3 values of garnets in kimberlites, derived from various source rocks. Pertinent details are discussed in the text and examples of different garnet populations are shown in various figures.

dispersed in the secondary (sedimentary) environment and sought in diamond exploration.

Efforts have been made to quantify the proportions of various types of garnet xenocrysts from kimberlites, in terms of pre-disaggregation mantle source rocks, using composi-

Significance of Eclogite and Cr-poor Megacryst Gamets in Diamond Exploration . D.J. SCHULZE

Table 3. Compositions of Cr-poor garnet megacrysts from various localities

351

Sample No.	SiO2'	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	Total	mg#	Add. Min.*
Premier Mine, South Africa												
13-57-49	41.69	1.00	21.23	1.97	7.99	0.30	20.74	4.74	0.08	99.74	0.8222	
13-57-50	41.14	1.35	20.71	1.27	11.33	0.35	18.79	4.70	0.10	99.74	0.7471	
13-57-48	41.10	0.92	21.37	1.62	10.58	0.44	18.42	5.26	0.08	99.79	0.7562	
13-57-47	41.47	1.15	20.94	2.31	8.62	0.33	19.87	5.06	0.09	99.84	0.8041	
13-57-46	41.83	1.07	21.35	0.75	10.11	0.27	20.11	4.35	0.10	99.94	0.7799	
13-57-44	41.47	1.01	21.37	0.52	12.18	0.34	18.65	4.55	0.10	100.19	0.7317	
13-57-43	41.37	1.16	21.14	0.51	12.23	0.36	18.72	4.64	0.11	100.24	0.7316	
13-57-42	41.87	0.75	20.94	2.65	7.75	0.28	20.77	4.85	0.07	99.93	0.8268	ILM
13-57-12	41.00	0.92	21.16	1.63	10.77	0.40	18.56	5.00	0.09	99.53	0.7543	
13-57-14	41.03	1.14	20.84	0.45	12.85	0.33	18.26	4.56	0.11	99.57	0.7168	
13-57-20	40.86	1.27	19.74	3.01	9.96	0.34	19.00	5.06	0.11	99.35	0.7726	
13-57-22	41.05	1.25	20.81	1.12	11.38	0.30	19.05	4.46	0.10	99.52	0.7489	
13-57-41	41.22	1.19	20.87	0.48	12.47	0.33	18.53	4.61	0.11	99.81	0.7258	
Monastery Mine, South Africa												
13-73-20	41.01	1.00	19.88	3.72	8.48	0.33	19.68	5.26	0.09	99.45	0.8052	
12-73-11	41.08	1.23	21.40	0.35	11.94	0.29	18.24	4.759	0.11	99.23	0.7313	
13-73-12	40.72	0.80	21.86	0.01	13.97	0.42	17.21	4.58	0.08	99.65	0.6869	ilm
13-73-10	41.00	1.26	21.23	0.53	11.69	0.31	18.77	4.69	0.10	99.58	0.7409	
13-73-9	41.19	1.20	21.29	0.65	10.85	0.27	19.33	4.66	0.10	99.54	0.7604	
3-73-8	41.03	1.12	21.53	0.30	11.99	0.32	18.56	4.55	0.11	99.51	0.7338	
3-73-7	41.01	1.16	21.13	0.35	11.83	0.37	18.50	5.20	0.08	99.63	0.7358	
3-73-6	41.21	1.17	21.38	0.66	10.73	0.28	19.45	4.57	0.10	99.55	0.7635	
3-72-70	41.35	1.21	21.40	0.63	10.94	0.35	19.10	4.66	0.10	99.74	0.7567	
3-72-74	41.48	1.15	21.66	0.53	11.18	0.35	19.10	4.61	0.10	100.16	0.7527	
3-72-71	41.73	1.20	21.32	0.98	9.72	0.32	19.91	4.78	0.09	100.05	0.7849	
13-73-18	40.97	1.19	21.58	0.57	11.48	0.28	19.01	4.53	0.10	99.71	0.7468	cpx
13-73-14	40.93	1.20	21.57	0.57	11.44	0.32	19.04	4.69	0.09	99.85	0.7478	cpx
13-73-19	40.69	0.72	22.21	0.01	14-05	0.38	17.28	4.42	0.07	99.83	0.6866	ol
13-73-24	41.06	1.20	21.50	0.55	11.69	0.29	18.92	4.61	0.09	99.91	0.7425	
13-73-23	41.52	1.10	21.82	0.74	10.41	0.29	19.85	4.44	0.09	100.26	0.7725	
13-73-22	41.14	1.23	21.38	0.68	10.92	0.28	19.39	4.64	0.09	99.75	0.7598	ol
Lace Mine, South Africa												
13-65-13	41.67	0.70	21.85	0.68	10.23	0.32	19.79	4.77	0.08	100.09	0.7751	cpx
3-65-80	42.05	0.61	22.23	0.75	10.10	0.33	20.03	4.57	0.07	100.74	0.7794	cpx
13-65-81	42.79	0.55	21.16	2.41	7.45	0.28	21.44	4.79	0.07	100.94	0.8368	cpx
13-65-82	41.29	0.74	21.79	0.44	11.04	0.34	18.96	4.46	0.09	99.15	0.7536	cpx
3-65-83	41.60	0.87	21.31	0.86	9.67	0.29	19.98	4.93	0.08	99.59	0.7863	
3-65-84	42.09	0.52	21.51	1.40	8.31	0.23	20.67	4.57	0.06	99.36	0.8159	
13-65-85	41.81	0.76	21.37	0.91	9.24	0.28	20.08	4.77	0.08	99.30	0.7947	
13-65-86	41.67	0.75	21.55	0.87	9.66	0.30	19.68	4.83	0.07	99.38	0.7840	
13-65-87	41.69	0.78	21.50	0.70	10.00	0.33	19.68	4.71	0.08	99.47	0.7780	
13-65-88	41.68	0.75	21.44	0.74	10.09	0.30	19.47	4.90	0.08	99.45	0.7746	
13-65-89	41.86	0.62	21.72	0.83	9.41	0.31	19.90	4.58	0.07	99.30	0.7902	
13-65-90	41.85	0.78	21.45	0.86	9.57	0.30	19.86	4.94	0.07	99.68	0.7871	
13-65-91	41.75	0.76	21.52	0.88	9.64	0.28	19.72	4.90	0.08	99.53	0.7847	
13-65-92	41.92	0.64	21.47	1.38	8.72	0.29	20.26	4.80	0.07	99.55	0.8054	
3-65-93	41.61	0.81	21.46	0.66	10.29	0.34	19.48	4.78	0.09	99.52	0.7713	
3-65-94	41.80	0.58	21.85	0.75	9.93	0.31	19.65	4.60	0.07	99.54	0.7790	
13-65-95	41.79	0.70	21.66	0.83	9.75	0.35	19.68	4.86	0.08	99.70	0.7824	
13-65-96	41.73	0.72	21.80	0.66	10.14	0.33	19.71	4.65	0.08	99.82	0.7759	
13-65-98	41.92	0.65	21.71	1.12	8.88	0.27	20.43	4.69	0.07	99.74	0.8038	
13-65-99	41.71	0.72	21.62	0.83	9.63	0.32	19.84	4.92	0.08	99.67	0.7859	
13-65-109		41.92	0.68	21.68	1.09	9.09	0.27	20.35	4.64	0.06	99.78	0.7995cpx
13-65-110		41.57	0.50	20.03	3.54	7.16	0.26	20.87	4.82	0.06	98.81	0.8385
13-65-111		41.83	0.56	21.46	1.46	8.63	0.27	20.56	4.53	0.05	99.35	C.8093cpx
13-65-112		41.28	0.87	21.65	0.42	11.20	0.36	18.77	4.84	0.07	99.46	0.7491cpx
13-65-113		41.25	0.85	21.45	0.47	11.53	0.36	18.54	4.79	0.07	99.31	0.7412cpx

13-65-114	42.00	0.54	21.49	1.37	7.72	0.25	21.19	4.59	0.05	99.20	0.8302cpx
13-65-115	41.13	0.92	21.47	0.33	11.97	0.36	18.20	5.19	0.07	99.64	0.7303cpx, ilm
13-65-116	41.53	0.57	21.06	1.94	8.21	0.26	20.61	4.75	0.06	98.99	0.8172cpx
13-65-117	41.40	0.66	21.45	1.07	9.08	0.26	20.18	4.71	0.06	98.87	0.7983cpx
13-65-119	41.18	0.78	21.67	0.35	11.74	0.37	18.52	4.61	0.07	90.29	0.7375cpx
13-65-120	41.78	0.62	21.69	1.06	9.31	0.30	20.09	4.58	0.05	99.48	0.7935cpx
13-65-122	41.57	0.64	21.64	0.98	9.39	0.30	20.12	4.56	0.06	99.26	0.7924cpx
13-65-123	41.44	0.62	21.95	0.61	10.21	0.33	19.65	4.48	0.06	99.35	0.7742cpx
13-65-124	41.02	0.88	21.51	0.37	11.93	0.38	18.23	5.05	0.08	99.45	0.7313cpx, ilm
13-65-125	41.48	0.70	21.94	0.45	11.12	0.35	19.10	4.50	0.06	99.70	0.7537cpx

352

Table 3. (continued)

Explor. Mining Geol., Vol. 6, No. 4, 1997

Sample No.	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	Total	mg#Add. Min.*
13-65-127	41.53	0.55	21.10	1.50	8.55	0.29	20.43	4.67	0.06	98.680.8097	
13-65-128	41.28	0.71	21.50	0.72	10.13	0.32	19.65	4.68	0.06	99.050.7755	
13-65-129	41.57	0.59	21.38	1.16	9.05	Q28	20.31	4.57	0.05	98.960.7999	
13-65-130	41.84	0.48	21.06	2.02	7.23	0.24	21.20	4.61	0.04	98.720.8393	
13-65-131	41.50	0.55	21.53	1.09	8.75	0.29	20.39	4.53	0.06	98.690.8059	
13-65-132	41.96	0.50	21.14	1.87	7.67	0.22	21.02	4.58	0.05	99.010.8300	
13-65-133	41.47	0.67	21.27	1.12	9.26	0.28	20.04	4.68	0.06	98.850.7940	
13-65-134	41.62	0.60	21.00	1.76	8.26	0.28	20.64	4.83	0.05	99.040.8165	
13-65-135	41.33	0.72	21.41	0.89	9.76	0.32	19.67	4.80	0.06	98.960.7821	
13-65-136	41.71	0.55	21.12	1.60	8.36	0.26	20.45	4.70	0.05	98.800.8133	
13-65-137	41.65	0.59	21.06	1.60	8.43	0.28	20.58	4.68	0.05	98.920.8130	
13-65-138	41.42	0.63	21.28	1.32	8.78	0.28	20.33	4.73	0.05	98.820.8049	
13-65-139	41.39	0.80	21.43	0.68	10.27	0.33	19.48	4.78	0.06	99.220.7716	
13-65-140	41.82	0.58	21.19	1.44	8.63	0.26	20.47	4.66	0.05	99.100.8086	
13-65-141	41.76	0.60	21.26	1.52	8.05	0.23	20.68	4.65	0.06	98.810.8207	
13-65-142	41.63	0.61	21.52	1.10	9.15	0.29	20.12	4.62	0.06	99.100.7966	
13-65-143	41.63	0.57	21.65	1.05	9.29	0.29	20.11	4.58	0.05	99.220.7941	
13-65-144	41.70	0.67	21.44	1.08	9.18	0.28	20.76	4.67	0.06	99.840.8011	
13-65-145	41.93	0.53	20.94	2.08	7.49	0.23	21.01	4.64	0.05	98.900.8332	
13-65-146	41.51	0.81	21.13	0.87	9.97	0.32	19.68	4.83	0.06	99.180.7786	
13-65-147	41.85	0.56	21.32	1.53	8.31	0.26	20.71	4.66	0.05	99.250.8161	
13-65-148	41.73	0.70	21.07	1.41	8.81	0.26	20.37	4.70	0.06	99.110.8046	
13-65-149	41.73	0.58	21.51	1.25	8.89	0.28	20.51	4.63	0.05	99.430.8043	
13-65-150	41.80	0.54	21.20	1.71	7.96	0.24	20.82	4.77	0.05	99.090.8233	
13-65-151	41.53	0.65	21.78	0.59	10.43	0.35	19.51	4.51	0.05	99.400.7692	
13-65-153	41.56	0.67	20.78	1.90	8.41	0.27	20.29	4.98	0.05	98.910.8112	
13-65-154	41.39	0.68	21.70	0.74	10.02	0.31	19.67	4.55	0.06	99.120.7776	
13-65-155	41.66	0.67	21.52	0.95	9.53	0.26	20.04	4.63	0.05	99.310.7893	
13-65-156	41.99	0.55	21.26	1.72	7.86	0.24	20.98	4.65	0.05	99.300.8262	
13-65-157	42.05	0.51	21.08	2.03	7.25	0.25	21.31	4.66	0.05	99.190.8396	
13-65-159	41.84	0.52	21.07	1.99	7.59	0.22	21.20	4.69	0.05	99.170.8326	
13-65-160	41.74	0.59	20.96	1.88	8.15	0.27	20.60	4.84	0.05	99.080.8183	
13-65-161	41.39	0.80	21.26	0.95	9.85	0.29	19.79	4.96	0.07	99.360.7816	
13-65-162	41.69	0.67	20.98	1.57	8.40	0.27	20.38	4.87	0.06	98.890.8121	
13-65-163	41.80	0.54	20.71	2.43	7.60	0.26	20.88	4.74	0.05	99.010.8303	
13-65~164	41.47	0.67	21.67	0.61	10.48	0.31	19.41	4.60	0.07	99.290.7674	
13-65-165	41.75	0.54	21.15	1.76	7.87	0.25	21.83	4.55	0.05	99.750.8317	
13-65-166	41.76	0.64	21.26	1.48	8.65	0.24	20.31	4.78	0.06	99.180.8070	
13-65-167	41.75	0.60	21.06	1.81	8.07	0.25	20.68	4.72	0.05	98.990.8203	
13-65-173	41.66	0.52	21.40	1.50	8.35	0.26	20.62	4.69	0.05	99.050.8148	
13-65-174	41.96	0.59	21.36	1.41	8.03	0.25	20.90	4.58	0.06	99.140.8226	
13-65-175	41.71	0.55	19.51	4.06	6.99	0.25	20.81	5.21	0.04	99.130.8413	
13-65-176	41.68	0.55	21.59	1.21	8.77	0.28	20.39	4.57	0.05	99.090.8055	
13-65-177	41.68	0.54	21.01	2.01	7.68	0.23	21.00	4.73	0.05	98.930.8297	
13-65-178	41.52	0.63	20.85	1.70	8.69	0.28	20.22	4.97	0.05	98.910.8056	
13-65-179	41.74	0.62	21.15	1.44	8.40	0.24	20.57	4.75	0.05	98.960.8135	
13-65-180	41.62	0.60	21.69	0.93	9.44	0.32	20.08	4.56	0.06	99.300.7912	
13-65-181	41.77	0.61	21.37	1.39	8.66	0.25	20.45	4.63	0.05	99.180.8079	
13-65-182	41.68	0.60	20.95	1.88	8.45	0.28	20.35	4.95	0.05	99.190.8110	
13-65-183	41.75	0.51	21.16	1.76	8.27	0.28	20.77	4.61	0.05	99.160.8173	
13-65-184	41.72	0.55	21.42	1.50	8.93	0.30	20.32	4.76	0.05	99.550.8021	
13-65-185	41.76	0.65	21.50	1.05	9.18	0.30	20.30	4.61	0.05	99.400.7975	
13-65-186	41.95	0.55	21.09	1.90	7.99	0.23	20.88	4.66	0.06	99.310.8232	
13-65-187	41.46	0.67	21.35	1.02	9.48	0.28	19.94	4.72	0.06	98.980.7893	
13-65-188	41.36	0.70	21.70	0.53	10.82	0.33	19.37	4.57	0.07	99.450.7613	
13-65-189	41.72	0.57	21.42	1.31	8.56	0.27	20.39	4.61	0.05	98.900.8093	

13-65-190	4L88	0.53	20.99	2.11	7.55	0.24	21.16	4.69	0.05	99.200.8331
13-65-191	41.78	0.56	21.44	1.44	8.53	0.27	20.69	4.58	0.05	99.340.8120
13-65-192	41,98	0.58	21.79	1.09	8.64	0.26	20.67	4.37	0.07	99.350.9099
13-65-193	41.52	0.74	21.01	1.70	8.47	0.26	20.61	4.82	0.06	99.190.8125
13-65-121	41.79	0.50	21.02	2.38	7.18	0.28	21.17	4.55	0.04	98.91 0~
13-65-198	41.90	0.64	21.26	1.65	8.26	0.24	20.79	4.68	0.05	99.470.8176

Kaalvallei Mine, South Africa

13-53-43	39.39	0.58	21.98	0.16	14.32	0.57	16.60	4.70	0.09	98.390.6737
13-53-44	39.20	0.45	22.17	0.16	14.12	0.62	16.21	5.41	0.07	98.410.6716
13-53-46	40.78	0.71	21.93	1.04	8.87	0.31	20.28	4.96	0.13	99.010.8029
13-53-47	39.59	0.56	22.43	0.04	14.39	0.55	16.93	4.37	0.10	98.960.6770
13-53-48	39.27	0.45	22.20	0.13	14.27	0.59	16.23	5.47	0.07	98.680.6695
13-53-49	40.39	0.78	21.97	0.75	9.39	0.35	19.77	5.01	0.15	98.560.7895

Significance of Eclogite and Cr-poor Megacryst Garnets in Diamond Exploration . D.J. ScHutzE

353

Table 3. (continued)

Sample No.	SiO2'	T102	A1203	Cr203	FeO	Mno	Mgo	CaO	Na20	Total	mg#	Add. Min.*
13-53-50	40.45	0.86	22.01	0.69	9.49	0.34	19.86	5.08	0.15	98.93	0.7885	
13-54-4	41.22	0.70	22.46	0.07	13.26	0.47	17.95	4.30	0.08	100.51	0.7068	ILM
13-52-72	41.18	0.55	22.38	0.15	14.38	0.54	17.21	4.44	0.07	100.90	0.6807	cpx
13-52-3	41.35	0.63	22.57	0.02	13.80	0.50	17.50	4.18	0.08	100.63	0.6931	ILM, cpx
13-54-42	41.94	0.91	21.61	1.11	8.93	0.21	20.67	4.44	0.09	99.91	0.8048	
13-54-43	41.00	0.68	22.17	0.33	12.88	0.48	17.69	4.87	0.07	100.17	0.7098	
13-54-44	40.94	0.99	21.74	0.10	12.94	0.42	18.06	4.67	0.09	99.95	0.7131	
13-54-3	41.07	0.81	22.08	0.10	13.33	0.42	17.79	4.37	0.09	100.06	0.7039	CM ilm
13-54-31	40.63	0.32	22.58	0.07	15.50	0.61	15.82	4.71	0.05	100.29	0.6451	CM ilm
13-54-33	41.15	0.77	22.09	0.59	12.63	0.47	18.12	4.45	10.08	100.35	0.7187	ILM, cpx
13-54-34	41.24	0.69	22.47	0.05	13.36	0.47	17.87	4.28	0.09	100.52	0.7044	ILM
13-54-35	41.13	0.87	22.06	0.05	13.27	0.43	17.97	4.42	0.09	100.29	0.7069	ILM
13-54-36	40.91	0.62	22.11	0.37	13.28	0.46	17.63	4.46	0.07	99.91	0.7028	ilm
13-54-37	41.18	0.53	22.56	0.11	13.46	0.49	17.57	4.44	0.07	100.41	0.6993	ilm
13-54-39	40.84	0.35	22.68	0.13	14.13	0.52	16.51	5.05	0.05	100.26	0.6755	cpx, ilm
13-52-73	40.89	0.41	22.51	0.15	14.23	0.50	16.41	5.45	0.07	100.62	0.6726	cpx
13-54-1	41.36	0.78	22.19	0.15	12.90	0.40	18.10	4.18	0.10	100.16	0.7142	ilm, cpx
13-53-62	40.71	0.60	22.04	0.04	15.02	0.51	16.62	4.33	0.08	99.95	0.6634	
13-52-31	40.90	0.87	21.63	0.06	13.07	0.40	17.94	4.54	0.09	99.50	0.7097	
13-52-50	41.66	0.85	21.85	0.64	9.55	0.28	19.88	4.79	0.13	99.63	0.7876	
13-52-57	41.49	0.90	21.85	0.40	10.31	0.29	19.42	4.83	0.12	99.61	0.7704	

Frank Smith Mine, South Africa

FRB 650.3	42.56	0.85	21.95	1.52	8.90	0.29	20.72	4.39	0.12	101.30	0.8057	ol
13-70-20	41.70	0.79	22.48	0.07	12.40	0.36	18.32	4.56	0.10	100.78	0.7246	ilm
12-99-1	41.87	0.79	22.79	0.02	11.53	0.36	18.65	4.56	0.09	100.66	0.7423	ILM
13-70-6	42.15	1.09	22.37	0.35	10.60	0.31	19.33	4.78	0.12	101.10	0.7646	ILM
13-70-23	42.09	1.17	21.63	1.30	9.77	0.31	19.62	4.84	0.10	100.83	0.7815	cpx
13-70-30	41.84	1.06	21.63	1.31	9.60	0.27	19.75	4.86	0.11	100.43	0.7856	cpx
13-70-16	41.92	1.25	21.51	1.25	10.11	0.27	19.61	4.79	0.13	100.84	0.7755	cpx
13-70-12	41.94	1.23	21.35	1.34	9.81	0.28	19.72	4.84	0.11	100.62	0.7817	cpx
13-70-13	41.87	1.22	21.35	1.31	10.04	0.29	19.68	4.68	0.12	100.56	0.7774	cpx
13-70-24	41.76	1.03	22.33	0.22	12.03	0.39	18.13	5.19	0.14	101.22	0.7286	ILM, opx
13-70-18	41.33	1.11	20.92	1.47	9.58	0.26	19.88	4.79	0.09	99.43	0.7871	
13-70-64	40.81	1.18	20.53	1.87	9.36	0.31	19.43	4.92	0.09	98.50	0.7871	
13-70-65	41.16	0.89	19.55	3.90	7.42	0.25	20.50	5.03	0.08	98.78	0.8311	
13-70-66	41.22	0.72	20.53	3.16	7.53	0.31	20.44	4.94	0.07	98.92	0.8296	
13-70-67	41.19	1.21	20.90	1.09	9.48	0.25	19.88	4.74	0.09	98.83	0.7888	
13-70-68	41.30	0.89	21.23	1.19	9.47	0.29	20.14	4.25	0.12	98.88	0.7911	
13-70-69	40.81	1.30	20.97	0.81	10.58	0.29	19.22	4.75	0.10	98.83	0.7639	
13-70-70	40.66	1.35	20.13	1.96	10.04	0.29	19.20	5.01	0.10	98.74	0.7731	
13-70-80	41.08	1.05	21.06	1.15	10.04	0.32	19.44	4.75	0.10	98.99	0.7752	
13-70-79	40.33	0.60	21.63	0.56	12.52	0.45	17.14	5.40	0.07	98.70	0.7092	
13-70-78	41.17	0.94	20.77	1.76	9.09	0.27	20.20	4.67	0.09	98.96	0.7983	
13-70-77	41.00	1.25	20.58	1.39	9.43	0.25	19.81	4.80	0.09	98.60	0.7891	
13-70-76	40.90	1.09	20.95	0.88	10.65	0.32	19.30	4.65	0.09	98.83	0.7635	
13-70-75	40.91	1.12	21.49	0.14	10.90	0.34	19.29	4.63	0.09	98.91	0.7592	
13-70-74	41.00	1.18	19.73	2.89	8.67	0.28	20.02	5.04	0.09	98.90	0.8044	
13-70-73	40.98	1.20	20.73	1.52	9.32	0.28	19.86	4.74	0.09	98.72	0.7915	
13-70-72	40.69	1.47	20.58	0.86	10.69	0.32	19.09	4.89	0.10	98.69	0.7608	
13-70-71	40.90	1.25	20.70	1.33	9.77	0.26	19.74	4.82	0.10	98.87	0.7826	
13-70-81	41.00	0.98	21.17	0.75	10.80	0.31	19.20	4.30	0.12	98.63	0.7600	
13-70-82	41.03	1.28	20.74	0.94	9.83	0.26	19.66	4.80	0.09	98.63	0.7808	

13-70-83	41.13	0.94	21.44	0.78	10.53	0.31	19.50	4.19	0.13	98.95	0.7674
13-70-84	40.73	1.28	20.70	1.07	10.14	0.28	19.21	4.82	0.10	98.33	0.7714
13-70-85	41.26	0.96	20.89	1.64	9.01	0.26	20.22	4.47	0.10	98.81	0.7999
13-70-86	40.72	1.28	19.87	2.57	9.10	0.32	19.51	5.20	0.08	98.65	0.7925
13-70-87	40.95	1.32	20.60	1.39	10.13	0.30	19.42	4.81	0.10	99.02	0.7735
13-70-88	40.90	1.02	21.07	1.28	10.27	0.33	19.35	4.56	0.10	98.88	0.7704
13-70-89	41.02	1.21	20.79	1.48	9.62	0.31	19.49	4.80	0.09	98.81	0.7830
13-70-90	41.14	1.20	20.80	1.39	9.70	0.28	19.71	4.81	0.10	99.13	0.7835
13-70-100	41.02	1.23	20.54	1.72	9.59	0.31	19.63	4.93	0.10	99.07	0.7848
13-70-99	41.02	0.70	22.22	0.04	11.92	0.37	18.51	4.53	0.08	99.39	0.7345
13-70-98	41.07	0.91	21.74	0.71	10.70	0.33	19.18	4.32	0.10	99.06	0.7615
13-70-97	41.20	1.04	20.99	1.26	9.15	0.25	20.19	4.63	0.08	98.79	0.7972
13-70-96	41.14	1.05	20.85	1.33	9.53	0.27	19.80	4.73	0.09	98.79	0.7873
13-70-95	41.03	0.96	21.01	1.34	9.66	0.28	19.79	4.69	0.08	98.84	0.7849
13-70-94	41.06	1.00	21.06	0.99	10.02	0.28	19.65	4.58	0.08	98.72	0.7774
13-70-93	40.81	1.19	20.71	1.55	9.56	0.28	19.66	4.84	0.08	98.68	0.7855
13-70-92	40.77	0.99	21.67	0.15	11.93	0.36	18.77	4.00	0.13	98.77	0.7370

354

Table 3. (continued)

Explor. Mining Geol., Vol. 6, No. 4, 1997

Sample No.	SiO2'	TiO2	Al2O3	Cr2O3	FeO	MnO	Mgo	CaO	Na2O	Total	mg#Add. min.*
13-70-91	40.86	1.17	20.66	1.73	9.46	0.28	19.56	4.88	0.09	98.69	0.7865
13-70-101	41.14	0.96	20.88	1.42	9.31	0.29	20.07	4.60	0.08	98.75	0.7934
13-70-111	41.18	1.00	21.01	1.81	9.04	0.27	19.76	4.53	0.21	98.81	0.7956
13-70-112	40.96	0.96	21.33	0.74	10.62	0.32	19.42	4.41	0.10	98.86	0.7651
13-70-102	40.79	1.21	20.56	1.74	9.30	0.27	19.76	4.66	0.17	98.46	0.7910
13-70-103	41.02	1.19	20.66	1.61	9.44	0.26	19.69	4.81	0.09	98.77	0.7879
13-70-113	41.12	1.19	20.95	1.32	9.83	0.30	19.67	4.75	0.09	99.22	0.7809
13-70-104	41.23	1.03	21.01	1.08	9.88	0.27	19.80	4.59	0.08	98.97	0.7812
13-70-105	40.92	1.38	19.83	2.45	9.54	0.30	19.31	5.24	0.10	99.07	0.7829
13-70-106	41.35	0.88	20.91	1.66	8.87	0.28	20.41	4.36	0.09	98.81	0.8039
13-70-107	40.84	1.29	20.62	1.43	10.08	0.27	20.62	4.91	0.10	100.16	0.7847
13-70-108	41.12	1.13	20.68	1.85	9.23	0.29	19.86	4.87	0.09	99.12	0.7931
13-70-109	40.93	1.10	21.48	0.18	11.75	0.37	18.68	4.61	0.10	99.20	0.7390
13-70-110	41.17	1.16	21.04	1.34	9.41	0.27	19.94	4.71	0.09	99.13	0.7905
13-70-60	40.87	1.06	20.86	1.55	9.58	0.26	19.58	4.75	0.09	98.60	0.7845 cpx
13-70-36	41.08	0.94	21.45	0.75	10.82	0.30	19.25	4.25	0.14	98.98	0.7601 cpx
13-70-41	41.30	0.98	21.52	0.85	10.47	0.30	19.54	4.51	0.13	99.60	0.7687 cpx
13-70-28	41.84	0.87	21.91	0.89	9.78	0.26	20.06	4.27	0.12	100.00	0.7851 cpx
Kao Mine, Lesotho											
13-117A	41.34	1.19	21.31	0.61	11.27	0.30	18.88	4.67	0.10	99.670.7490	
13-117-2	41.94	0.96	21.51	1.01	9.12	0.25	20.45	4.51	0.07	99.820.7998	
13-117-3	42.05	0.93	21.54	1.06	8.81	0.22	21.74	4.42	0.07	100.840.8147	
13-117-4	41.69	1.08	21.57	0.74	10.23	0.26	19.65	4.49	0.09	99.800.7738	
13-117-5	41.73	1.09	21.36	0.84	10.00	0.27	19.91	4.52	0.08	99.800.7800	
13-117-6	41.84	0.99	21.60	0.88	9.85	0.27	20.04	4.41	0.09	99.970.7837	
13-117-7	41.44	1.24	21.40	0.48	11.58	0.31	18.76	4.70	0.10	100.010.7426	
13-117-8	41.62	1.02	21.65	0.55	10.83	0.31	19.28	4.48	0.10	99.840.7602	
13-117-16	41.25	1.15	21.49	0.56	12.09	0.32	18.31	4.57	0.09	99.830.7296	
13-117-15	41.56	1.15	21.52	0.69	10.68	0.30	19.29	4.58	0.09	99.860.7629	
13-117-14	42.06	0.87	21.52	1.53	8.62	0.25	20.78	4.47	0.07	100.170.8111	
13-117-13	42.04	0.94	21.73	0.85	9.43	0.28	20.30	4.34	0.09	100.000.7931	
13-117-12	41.60	1.11	21.51	0.70	10.58	0.29	19.47	4.56	0.09	99.910.7662	
13-117-11	41.53	1.09	21.63	0.64	10.61	0.30	19.40	4.52	0.08	99.800.7651	
13-117-10	41.28	0.86	22.07	0.08	13.08	0.36	17.88	4.47	0.09	100.170.7089	
13-117-9	41.78	1.12	21.52	0.68	10.70	0.29	19.35	4.60	0.09	100.130.7631	
13-117-17	41.52	1.28	21.37	0.53	11.58	0.33	18.83	4.65	0.10	100.190.7434	
13-117-18	41.92	0.80	21.74	0.95	9.18	0.25	20.56	4.29	0.08	99.770.79%	
13-117-19	42.13	0.93	21.54	1.08	8.97	0.25	20.50	4.51	0.08	99.990.8028	
13-117-20	41.28	1.33	21.04	0.75	11.45	0.30	18.86	4.54	0.11	99.660.7458	
13-117-21	41.76	1.05	21.49	0.91	9.78	0.25	20.00	4.53	0.08	99.850.7846	
13-117-22	42.00	1.01	21.48	0.89	9.64	0.25	20.08	4.48	0.09	99.920.7877	
13-117-23	42.01	0.99	21.40	0.97	9.16	0.24	20.31	4.50	0.08	99.660.7980	
13-117-24	42.07	1.00	21.49	1.12	9.09	0.23	20.44	4.54	0.08	100.060.8002	
13-117-32	42.01	0.99	21.62	1.03	9.13	0.25	20.40	4.54	0.08	100.050.7992	
13-117-31	42.19	0.79	21.89	0.97	8.96	0.23	20.62	4.31	0.08	100.040.8039	
13-117-30	42.06	1.00	21.65	0.86	9.73	0.25	20.05	4.47	0.09	100.160.7859	
13-117-29	42.18	0.94	21.62	1.08	9.00	0.26	20.71	4.44	0.07	100.300.8039	
13-117-28	42.09	1.00	21.57	1.00	9.15	0.25	20.40	4.52	0.08	100.060.7988	

13-117-27	41.42	1.18	21.50	0.47	11.40	0.30	18.88	4.59	0.10	99.840.7468
13-117-26	41.15	0.67	22.25	0.02	14.09	0.43	16.98	4.46	0.08	100.130.6822
13-117-25	41.87	0.99	21.52	0.97	9.37	0.26	20.33	4.49	0.07	99.870.7944

Thaba Putsoa, Lesotho

PHN6415	41.41	1.00	21.93	0.46	11.37	0.29	18.74	4.24	0.10	99.550.7460
13-120-1	41.88	0.97	21.57	1.14	9.10	0.24	20.18	4.51	0.09	99.670.7979
13-120-2	41.62	1.10	21.71	0.73	10.40	0.28	19.36	4.58	0.09	99.880.7682
13-120-3	41.53	1.13	21.62	0.68	10.58	0.30	19.16	4.59	0.09	99.680.7634
13-120-4	41.91	0.83	22.04	1.03	9.11	0.25	20.30	4.30	0.09	99.860.7988
13-120-5	41.45	1.20	21.66	0.61	10.88	0.29	18.95	4.64	0.09	99.740.7562
13-120-6	41.92	1.01	21.54	1.15	8.94	0.22	20.44	4.51	0.08	99.800.8028
13-120-7	41.23	1.10	21.73	0.34	11.97	0.34	18.22	4.53	0.10	99.560.7306

Letseng-la-Terae Mine, Lesotho

13-115-1	41.10	1.04	21.53	1.20	8.88	0.23	20.86	4.33	0.09	99.260.8071
13-115-2	41.38	1.19	21.64	0.42	11.75	0.32	18.70	4.57	0.11	100.080.7392
13-115-3	41.70	1.16	21.46	0.79	10.36	0.29	19.63	4.61	0.09	100.090.7714
13-115-4	41.72	1.07	22.03	0.43	11.22	0.28	19.25	4.22	0.10	100.320.7535
13-115-5	42.19	1.03	21.89	0.73	9.92	0.28	20.01	4.47	0.08	100.600.7823
13-115-6	42.10	1.04	21.59	0.88	9.71	0.25	20.27	4.56	0.08	100.480.7881

Significance of Eclogite and Cr-poor Megacryst Garnets in Diamond Exploration . D.J. SCHULZE

Table 3. (continued)

355

Sample No.	SiO2'	TEO2	A1203	Cr203	FeO	Mno	Mgo	CaO	Na20	Total	mg#	Add. Min.*
13-115-7	42.01	1.21	21.41	0.81	10.12	0.26	19.88	4.68	0.09	100.47	0.7777	
13-115-8	41.73	1.16	21.86	0.20	12.19	0.36	18.49	4.57	0.11	100.67	0.7299	
13-115-10	41.68	1.08	21.93	0.45	11.53	0.31	19.13	4.30	0.10	100.51	0.7472	
13-115-11	42.07	1.00	21.75	0.95	9.58	0.24	20.26	4.48	0.09	100.42	0.7902	
13-115-12	42.02	1.01	21.63	0.95	9.22	0.25	20.48	4.50	0.09	100.15	0.7982	
13-115-13	41.84	1.05	21.94	0.51	11.11	0.30	19.31	4.27	0.10	100.43	0.7559	
13-115-14	41.79	1.03	21.86	0.46	11.18	0.30	19.28	4.30	0.12	100.32	0.7544	
13-115-18	41.84	1.09	21.69	0.64	10.39	0.27	19.75	4.49	0.09	100.25	0.7720	
13-115-17	41.86	1.06	21.74	0.78	10.03	0.25	19.96	4.48	0.08	100.24	0.7800	
13-115-16	41.78	1.14	21.61	0.72	10.49	0.30	19.53	4.55	0.10	100.22	0.7683	
13-115-15	42.04	0.98	21.76	0.90	9.65	0.26	20.15	4.37	0.09	100.20	0.7881	

Iron Mountain 26, Wyoming, U.S.A.

13-94-10	41.42	0.70	21.38	2.28	8.37	0.28	20.39	5.05	0.05	99.92	0.8127	
13-94-11	41.16	0.85	21.25	1.83	9.30	0.28	19.75	5.18	0.05	99.65	0.7909	
13-94-12	41.34	0.76	21.53	1.70	9.29	0.29	19.83	5.14	0.04	99.92	0.7918	
13-94-13	41.37	0.67	21.28	2.34	8.55	0.26	20.21	5.19	0.05	99.92	0.8081	
13-94-14	41.43	0.60	21.59	2.10	8.29	0.27	20.46	4.96	0.04	99.74	0.8147	
13-94-15	41.56	0.62	21.77	1.78	8.35	0.26	20.54	4.89	0.04	99.81	0.8142	
13-94-16	41.62	0.82	21.56	1.58	9.29	0.29	19.82	5.06	0.05	100.09	0.7917	
13-94-17	41.82	0.65	21.33	2.23	8.48	0.28	20.37	4.99	0.04	100.19	0.8106	
13-94-18	41.64	0.88	21.42	1.85	8.93	0.26	20.12	5.16	0.05	100.31	0.8005	
13-94-19	41.32	0.89	21.95	0.82	11.13	0.35	18.91	4.94	0.06	100.37	0.7516	
13-94-20	41.35	0.91	21.77	0.87	10.95	0.33	18.99	5.02	0.06	100.25	0.7554	
13-94-21	42.00	0.55	21.37	2.54	8.01	0.25	20.72	4.93	0.04	100.41	0.8217	
13-94-22	41.47	0.87	21.80	0.84	10.98	0.33	18.90	4.97	0.06	100.22	0.7541	
13-94-23	41.79	0.53	20.83	3.16	7.59	0.25	20.81	5.00	0.04	100.00	0.8300	
13-94-24	41.74	0.56	21.58	2.08	8.67	0.30	20.31	4.89	0.04	100.17	0.8067	
13-94-25	41.57	0.60	20.50	2.25	8.71	0.26	20.17	4.89	0.05	99.00	0.8049	
13-94-26	41.70	0.63	21.45	2.17	8.77	0.28	20.19	4.92	0.04	100.15	0.8039	
13-94-27	41.63	0.78	21.62	1.75	9.27	0.27	19.90	4.98	0.04	100.24	0.7927	
13-94-28	41.91	0.60	21.44	2.43	8.18	0.26	20.58	4.95	0.04	100.39	0.8176	
13-94-29	41.79	0.70	21.72	1.72	9.38	0.31	20.02	5.01	0.05	100.70	0.7917	
13-94-30	40.96	0.54	22.39	0.28	13.66	0.45	17.38	4.74	0.05	100.45	0.6938	
13-94-31	41.48	0.89	21.33	1.72	9.68	0.28	19.58	5.14	0.05	100.15	0.7827	
13-94-32	41.28	0.91	21.31	1.63	9.90	0.31	19.36	5.35	0.06	100.11	0.7769	
13-94-33	41.13	0.95	22.10	0.15	12.55	0.37	17.79	5.31	0.07	100.42	0.7163	
13-94-34	41.87	0.69	21.78	1.59	9.43	0.28	19.94	4.86	0.05	100.49	0.7902	
13-94-35	41.56	0.80	21.67	1.53	9.74	0.30	19.69	5.06	0.05	100.40	0.7826	
13-94-36	41.82	0.53	21.76	2.22	8.35	0.26	20.51	4.95	0.04	100.44	0.8140	
13-94-37	41.90	0.64	21.75	1.98	8.56	0.27	20.50	4.89	0.04	100.53	0.8101	

Carmel Mine, South Africa

13-76-4	42.07	0.74	22.14	0.83	9.31	0.29	19.69	5.00	0.07	100.14	0.7902	
13-76-5	41.95	0.96	21.97	0.65	8.82	0.28	19.86	5.51	0.07	100.07	0.8004	

13-76-6	41.87	1.12	21.61	0.65	9.55	0.32	19.49	5.62	0.09	100.32	0.7843
13-76-7	42.44	1.15	22.42	0.41	7.00	0.24	21.06	5.63	0.09	100.44	0.8427
13-76-8	41.94	0.77	22.20	0.76	9.15	0.31	19.96	4.95	0.06	100.10	0.7953
13-76-9	42.36	0.61	22.58	0.69	8.97	0.31	20.23	4.46	0.06	100.27	0.8007

Pine Creek 01, Australia

13-90-1	41.71	0.63	22.62	0.64	10.00	0.32	19.13	4.81	0.05	99.91	0.7731
13-90-2	41.85	0.52	22.73	0.87	8.77	0.30	19.86	4.82	0.04	99.76	0.8013
13-90-3	41.40	0.70	22.19	0.96	9.99	0.30	19.04	4.85	0.06	99.49	0.7725
13-90-4	41.58	0.71	21.88	1.53	9.35	0.29	19.49	4.82	0.05	99.70	0.7878
13-90-5	41.61	0.64	22.17	1.19	9.67	0.28	19.27	4.78	0.06	99.67	0.7802
13-90-6	41.73	0.69	22.51	0.71	9.82	0.28	19.36	4.76	0.06	99.92	0.7783
13-90-7	41.73	0.71	22.34	0.95	9.79	0.31	19.29	4.88	0.06	100.06	0.7783
13-90-8	41.61	0.71	22.41	0.95	9.92	0.30	19.24	4.73	0.07	99.94	0.7755
13-90-9	41.61	0.60	22.78	0.35	11.15	0.34	18.48	4.65	0.05	100.01	0.7470
13-90-10	41.45	0.71	22.38	0.84	9.97	0.31	19.07	4.73	0.05	99.51	0.7731
13-90-11	41.41	0.62	22.63	0.45	10.96	0.34	18.56	4.58	0.06	99.61	0.7510
13-90-12	41.48	0.64	22.51	0.83	9.91	0.31	19.13	4.85	0.06	99.72	0.7747

Sloan, Colorado, U.S.A.

13-15-9	41.11	0.81	21.59	1.21	10.64	0.39	19	4.79	0.07	99.61	0.7608	opx
13-15-16	40.98	0.63	21.43	2.12	9.57	0.38	19.34	5.08	0.06	99.31	0.7826	
13-15-36	40.87	0.76	19.55	4.3	9.15	0.37	19.32	5.01	0.07	99.4	0.7900	ilm
13-15-89	41.07	0.99	20.86	1.9	10.28	0.37	18.99	5.08	0.07	99.61	0.7669	
13-15-90	41.39	0.83	20.47	2.75	8.09	0.28	20.51	5.03	0.06	99.41	0.8187	

356

Table 3. (continued)

Explor. Mining Geol., Vol. 6, No. 4, 1997

Sample No.	SiO2*	TiO2	Al2O3	Cr2O3	FeO	MnO	MgO	CaO	Na2O	Total	mg#Add. Min.*
13-15-91	40.87	1.08	20.39	2.28	10.52	0.35	18.76	5.21	0.08	99.540.7606	
13-15-95	40.71	0.73	19.99	3.97	9.50	0.37	19.34	4.96	0.05	99.310.7838	
13-16-5	40.73	0.75	19.92	3.93	9.49	0.38	19.31	5.02	0.05	99.310.7837	
13-16-6	40.75	0.67	20.16	3.70	10.16	0.40	19.21	4.68	0.06	99.310.7710	
13-16-7	41.03	0.69	19.88	4.23	9.51	0.37	19.41	4.82	0.06	100.000.7842	
13-16-8	41.75	0.83	20.65	2.61	8.15	0.28	20.64	5.05	0.06	100.020.8185	
13-16-9	40.65	0.79	18.78	5.18	9.33	0.37	18.75	5.46	0.06	99.370.7815	
13-16-11	41.76	0.68	20.14	3.46	7.46	0.27	20.95	5.07	0.05	99.840.8333	
13-16-12	41.26	0.93	21.21	1.57	10.34	0.35	19.04	5.06	0.08	99.830.7664	
13-16-13	41.57	0.77	21.08	2.04	8.83	0.31	20.23	4.95	0.06	99.840.8031	
13-16-14	41.10	1.08	20.09	2.79	10.05	0.33	18.99	5.44	0.07	99.930.7710	
13-16-15	41.02	0.97	20.87	1.71	10.41	0.32	19.04	5.02	0.07	99.430.7652	
13-16-16	41.73	0.87	20.56	2.60	8.27	0.26	20.53	5.06	0.06	99.930.8155	
13-16-17	41.02	0.71	20.17	3.70	9.14	0.39	19.25	5.45	0.06	99.890.7895	
13-16-18	41.76	0.88	20.79	2.49	8.62	0.28	20.38	5.10	0.06	100.350.8082	
13-16-19	41.11	1.05	20.98	1.46	10.49	0.35	18.98	5.04	0.08	99.540.7631	
13-16-20	41.58	0.81	20.76	2.45	8.38	0.29	20.45	5.00	0.06	99.780.8129	
13-16-21	41.77	0.64	20.59	2.99	7.75	0.26	20.86	4.91	0.05	99.830.8273	
13-16-22	41.27	0.94	21.48	1.02	10.79	0.39	18.87	4.90	0.07	99.730.7570	
13-16-23	40.88	0.74	19.38	4.80	8.76	0.36	19.39	5.16	0.06	99.520.7977	
13-16-24	41.29	0.94	21.35	1.49	10.29	0.34	19.21	4.84	0.08	99.840.7687	
13-16-25	40.71	0.94	18.90	4.40	9.74	0.39	18.54	5.90	0.08	99.580.7723	
13-17-2	40.40	0.99	18.89	4.59	9.03	0.33	18.96	5.87	0.07	99.130.7889	
13-17-9	40.88	0.93	20.89	1.91	10.23	0.34	19.23	5.03	0.08	99.310.7701	
13-17-21	41.10	0.68	21.76	1.39	10.51	0.36	19.60	4.31	0.06	99.310.7686	
13-17-23	40.78	1.11	20.60	1.70	10.62	0.36	18.74	5.27	0.08	99.310.7586	
13-17-24	41.19	0.67	21.81	1.53	10.41	0.35	19.58	4.29	0.06	99.310.7701	
13-17-27	41.15	0.61	21.68	1.78	10.22	0.38	19.68	4.44	0.05	100.000.7743	
13-17-28	40.93	0.93	20.43	2.74	9.38	0.34	19.60	5.17	0.07	99.310.7883	
13-17-29	40.77	0.96	20.78	1.93	10.27	0.36	19.14	5.11	0.08	99.310.7686	
13-17-31	41.38	0.82	19.25	4.80	8.83	0.33	19.20	5.79	0.07	100.480.7947	
13-17-44	40.33	0.83	19.35	4.26	9.79	0.40	18.56	5.68	0.07	99.260.7715	
13-17-45	40.67	0.82	19.72	3.90	9.66	0.41	19.11	5.24	0.06	99.590.7789	
Winkler, Kansas, U.S.A.											
13-29-2	41.32	0.72	21.48	2.34	7.41	0.24	20.71	5.26	0.04	99.520.8328	
13-29-3	41.39	0.87	22.04	1.26	8.50	0.26	20.14	5.21	0.04	99.710.8085	
13-29-4	41.28	0.81	21.22	2.61	7.74	0.28	20.43	5.29	0.05	99.710.8245	
13-29-5	40.09	0.96	22.80	1.45	9.84	0.28	19.39	4.79	0.07	99.670.7784	
13-29-6	41.15	1.24	20.09	3.54	7.16	0.22	20.56	5.75	0.05	99.760.8364	
13-29~7	41.20	1.00	21.21	2.13	8.79	0.26	19.88	5.39	0.06	99.940.8011	

13-29-8	41.06	1.00	21.22	1.98	8.74	0.26	19.84	5.32	0.06	99.480.8018
13-29-9	40.91	0.98	20.78	2.53	8.73	0.30	19.74	5.42	0.06	99.440.8011
13-29-10	41.31	0.64	21.67	2.29	7.71	0.30	20.44	5.19	0.04	99.600.8253
13-29-11	41.15	0.96	21.82	1.26	9.38	0.26	19.61	5.14	0.06	99.640.7884
13-29-12	41.02	0.92	20.56	3.33	8.17	0.29	19.97	5.53	0.05	99.840.8132
13-29-13	41.15	0.87	21.49	1.84	8.58	0.29	19.92	5.28	0.05	99.470.8052
13-29-14	40.95	1.06	20.76	2.59	8.64	0.29	19.61	5.54	0.07	99.520.8017
13-29-15	40.95	0.85	20.80	2.92	8.07	0.26	19.94	5.43	0.05	99.270.8148
13-29-17	41.22	1.08	21.53	1.84	8.83	0.29	19.86	5.30	0.06	100.000.8002
13-29-18	41.37	1.11	22.56	0.39	9.34	0.31	20.76	3.78	0.08	99.700.7983
13-29-19	41.28	0.88	21.86	1.53	8.14	0.26	20.38	5.26	0.05	99.640.8168
13-29-20	41.34	0.86	21.68	1.86	7.95	0.27	20.44	5.23	0.05	99.670.8208
13-29-21	41.29	0.91	21.58	1.73	8.42	0.26	20.46	5.08	0.05	99.790.8123
13-29-22	41.51	0.87	21.73	1.73	7.80	0.29	20.74	5.26	0.04	99.970.8257

L-one Tree, Kansas, U.S.A.

13-28-5	41.27	0.79	20.54	3.29	7.26	0.25	20.54	5.46	0.04	99.440.8343
13-28-6	41.42	0.78	20.55	3.58	7.99	0.26	20.05	5.62	0.06	100.300.8172
13-28-7	41.17	0.82	20.38	3.56	8.01	0.28	20.00	5.63	0.04	99.890.8164
13-28-8	41.36	0.83	20.94	2.81	7.26	0.24	20.63	5.44	0.04	99.550.8349
13-28-9	41.16	1.08	22.32	0.06	10.51	0.34	19.17	5.23	0.06	99.930.7647
13-28-10	41.39	0.76	21.33	2.53	8.19	0.30	20.06	5.43	0.05	100.050.8136
13-28-11	41.01	1.14	22.28	0.09	10.30	0.33	18.90	5.62	0.07	99.740.7657
13-28-12	41.72	0.56	22.21	1.62	7.72	0.26	20.82	4.99	0.04	99.960.8277
13-28-13	41.54	0.78	22.01	1.56	8.45	0.24	20.38	5.22	0.05	100.230.8112
13-28-14	41.64	0.69	21.34	2.44	7.53	0.25	20.68	5.25	0.04	99.860.8304
13-28-16	41.17	0.76	20.71	2.79	8.26	0.29	19.79	5.68	0.05	99.500.8102
13-28-17	41.44	0.74	20.40	3.72	6.72	0.27	20.66	5.52	0.04	99.510.8456

+ All values in wt%; *mg molar Mg/(1V1g+Fe); * additional minerals; upper case indicates host mineral, if garnet is not the host; abbreviations: ilm clinopyroxene, ol - olivine, opx - orthopyroxene

- ilmenite, cpx -

tional criteria (Lucas et al., 1989; Schuize, 1989, 1993a, 1994). These results are useful in predicting the relative proportions of the various types of mantle-derived garnets that should be recovered in the course of kimberlite and diamond exploration programs. Some of the chemical criteria useful in such classification are discussed in the next section.

Analysis and classification of approximately 4500 garnet xenocrysts from 32 kimberlites in South Africa and North America (Schulze, 1993a, 1994) has shown an average of 62% are derived from peridotites, 10% from eclogites and 28% from Cr-poor megacrysts. These values are skewed, from a worldwide perspective, by the fact that most Group II kimberlites (defined by Smith, 1983), which are restricted to southern Africa (Skinner, 1989), lack Cr-poor megacrysts. Furthermore, the Roberts Victor kimberlite (also Group II) has an anomalously high abundance of eclogitic garnet xenocrysts (39% peridotite, 61% eclogite; also see Gurney and Kirkley, 1996). Proportions for Group I kimberlites, worldwide, are 62% peridotite, 4% eclogite and 34% Cr-poor megacryst.

Within North America, only the Lake Ellen kimberlite in Michigan has been shown to have a large population of eclogite garnets (18%), and it also has a substantial population of Cr-poor megacryst garnets (46%) (Schuize, 1993a). Many other North American kimberlites have low eclogite abundances, but have substantial proportions of Cr-poor megacryst garnets. For example, kimberlites from A-4 and B-30 in Kirkland Lake, IG-3 in Wyoming, and Lone Tree in Kansas have 66% to 70% megacryst garnets in their heavy mineral garnet populations, but only from <1 % to 3% eclogite garnets (Schulze, 1993a). These values suggest that whereas few eclogitic garnets should typically be expected to be found in kimberlite exploration programs, relative to peridotite-derived Cr-pyropes, orange garnets from the Cr-poor megacryst suite should commonly be abundant, and in some cases dominant.

Much of the current interest in diamond exploration in Canada and northern Europe (for example) is concentrated in regions of Precambrian Shield where bedrock sources and glacial deposits contain abundant metamorphic garnets of crustal origin. The task of the kimberlite explorationist in Canada, Europe, and many other regions worldwide, is thus to select mantle-derived garnets (with a kimberlite source) from the myriad of crustal garnets in an exploration sample. Most Cr-pyropes are distinctive in their red to purple color and Mg- and Cr-rich compositions. Selecting orange mantle-derived garnets (eclogitic and Cr-poor megacryst-derived) from the orange and pink crustal almandines (that can be very abundant) represents a much greater challenge.

Compositional Distinction of Garnet Suites in Kimberlites

Peridotite Garnets

Peridotite-derived xenocrysts of Cr-rich pyrope are by far the most useful garnets in kimberlite exploration, and

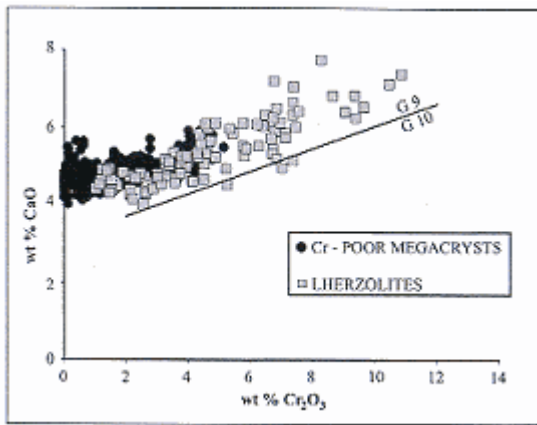


Fig. 2. CaO-Cr₂O₃ variations of garnets from lherzolites and Cr-poor megacrysts, illustrating a significant overlap. "G 1 W" and "GT" on the solid line indicate the subdivision of peridotitic garnets by Gurney (1984). Garnet lherzolite data from Nixon and Boyd (1973b), Cox et al. (1973), Smith (1977), Boyd and Nixon (1978), Viljoen et al. (1994) and Cr-poor garnet megacryst data from Nixon and Boyd (1973a), Smith (1977), Robey (1981), Schuize (1982, this paper, Table 3) and de Bruin (1991).

have been used for more than a century. In addition to simply indicating the presence of kimberlite, in their compositions they may carry information about the diamond potential of their kimberlite sources (i.e., the GIO [harzburgitic] vs G9 [lherzolitic garnet interpretation - see, for example, Gurney and Switzer, 1973; Sobolev et al., 1973; Sobolev, 1977; Gurney, 1984, 1989; Fipke et al., 1989, 1995; Gurney et al., 1993; Gurney and Zweistra, 1995). The reader is referred to these publications for detailed discussion of peridotite garnets in diamond exploration. Cutoff values of 2.0 wt% Cr₂O₃ (Gurney, 1984) and 0.5 wt% Cr₂O₃ (Schulze, 1989) have been suggested to discriminate between Cr-rich peridotitic garnets and the lower Cr₂O₃ eclogite xenocrysts.

Peridotite Garnets vs Cr-poor Megacryst Garnets

Another suite of garnets, those from Cr-poor megacrysts, also known as "discrete nodules" (Nixon and Boyd, 1973a; Eggler et al., 1979; Gurney et al., 1979; Schulze, 1987), is volumetrically important in many kimberlites (as shown above) and overlaps in some compositional characteristics with both peridotitic and eclogitic garnets. In terms of Cal(Ca+Mg+Fe) values, Cr-poor garnet megacrysts, having equilibrated with both clinopyroxene and orthopyroxene (Gurney et al., 1979) are chemically equivalent to lherzolite garnets, and thus plot together with lherzolite (i.e., G9) garnets on a CaO-Cr₂O₃ diagram, but at relatively low Cr₂O₃ values, typically <4 wt% Cr₂O₃ (Fig. 2). These two suites can be largely distinguished using other chemical parameters, however, such as generally higher FeO, TiO₂ and Na₂O contents of Cr-poor megacryst garnets

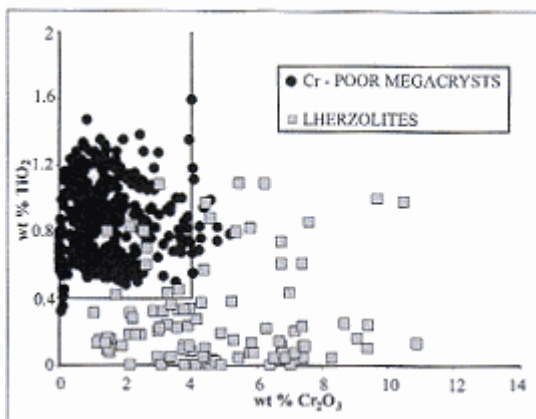


Fig. 3. Variation of TiO₂ and Cr₂O₃ in garnets from lherzolites and Cr-poor megacrysts. Data sources as in Figure 2. The two suites of garnets are effectively separated, with minimal overlap, if Cr-poor megacryst garnets are defined as having >0.4 wt% TiO₂ and <4.0 wt% Cr₂O₃, as indicated by the solid lines. Most of the Cr-poor megacryst garnets with >4.0 wt% Cr₂O₃ on this diagram are from the Sloan kimberlite. Peridotite garnets with elevated TiO₂ contents are typically from deformed ("sheared") xenoliths with high equilibration temperatures (Nixon and Boyd, 1973a).

relative to most peridotite garnets. In Figure 3, minimal overlap of the two populations is illustrated, and Cr-poor megacryst garnets are defined on this diagram as having <4 wt% Cr₂O₃ and >0.4 wt% TiO₂. Most peridotite garnets with elevated TiO₂ contents are from high-temperature deformed ("sheared") garnet peridotites (Nixon and Boyd, 1973b). Distinction between Cr-poor megacryst garnets and those from eclogites is discussed below.

Crustal Garnets vs Eclogitic Garnets

Although garnets derived from crustal rocks occur in small numbers in many kimberlites, they typically dominate the garnet populations of heavy mineral suites in exploration samples. Chemical screens must be employed to discriminate between crustal orange garnets and those with mantle (i.e., kimberlite) sources, in cases in which color and inorphology are not diagnostic criteria.

Crustal garnets and those from mantle eclogites overlap with each other in terms of Cr2O3 and CaO (Fig. 4). Minor differences exist in Figure 4 in that some eclogite garnets have moderate Cr2O3 values, relative to the near zero Cr2O3 values of most crustal garnets, and some crustal garnets (primarily those from metapelites) can have very low CaO contents (<1.0 wt%), whereas most eclogite garnets have >3.5% CaO. The two suites can be distinguished using other chemical criteria, however, as shown in Figure 5. On this diagram, a cutoff value of 22% FeO would essentially distinguish the two suites, with eclogite garnets also having generally higher TiO2 contents than the crustal garnets.

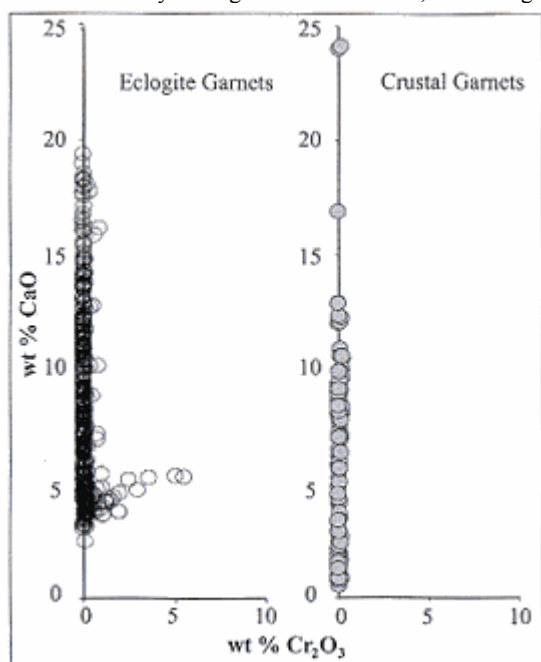


Fig. 4. CaO and Cr2O3 contents of garnets from mantle eclogites and crustal rocks. Eclogite data from McCandless and G~ (1986), Ater (1982), Ford (1987), Shee (1978), Tollo (1982), Smyth and Caporuscio (1984), Hall (1985), Schulze and Helmstaedt (1988), Moore (1986) and diamond eclogite references in Figures 6 and 8. Crustal garnet data from Azor and Balkyre (1997), B6gin and Pattison (1994), Fitzsimons (1996), Fitzsimons and Harley (1994), Gordon et al. (1991, 1994), Guiraud et al. (1996), Hartel and Pattison (1996), Knudsen (1996), Kryza et al. (1996), Nyman et al. (1995), Pattison (1991), Pattison and Bdgin (1994), Pattison et al. (1982), Percival (1981), 7boni and Miller (1996), Willner et al. (1997) and Whitney et al. (1996).

Classification of Mantle Eclogites

Mantle eclogites are divided, on the basis of their textures and compositions, into Groups I and II (MacGregor and Carter, 1970; Hatton, 1977; McCandless and Gurney, 1989). Although the textural classification can be ambiguous, chemical distinction, based on Na2O content of garnet and K2O content of coexisting clinopyroxene, is definitive in many suites. For example, clear differences in Na2O in garnet and K2O in clinopyroxene allow separation into two groups at Roberts Victor (McCandless and Gurney, 1986), Bobbejaari (Smyth and Caporuscio, 1984), Sloan (Schulze, 1992) and Kaalvallei (Viljoen, 1994), although exact compositional divisions and ranges vary between localities. Based on earlier observations by MacGregor and Carter (1970) and Sobolev and Lavrent'ev (1972), McCandless and Gurney (1989) suggested that Group I eclogites have values of Na2O in garnet ~0.09 wt% or K2O in clinopyroxene > 0.08, with Group II eclogites having lower values. Using these criteria, most diamondiferous eclogites would be classified as Group I eclogites, in agreement with

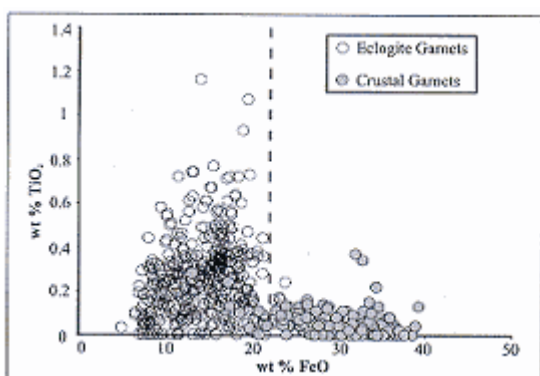


Fig. 5. Discrimination between garnets from mantle eclogites and crustal rocks in terms of TiO2 and FeO contents. Data sources as in Figure 4.

Robinson et al. (1984) and McCandless and Gurney (1989). Using a Na2O cutoff value for garnets of ~0.07 wt%, as specifically suggested for diamond exploration applications by Gurney (1984) and Fipke et al. (1995), results in classification of almost all

diamondiferous eclogites as Group 1 (Fig. 6). Data used in Figure 6 represent most published analyses of diamond eclogites, and new analyses of additional diamond eclogites from the Udachnaya Mine in Siberia (Table 1) which are included here to expand the published data set for this rare rock type. Typical Group II eclogites are not known to contain diamonds, and thus the chemical characteristics of their garnets and clinopyroxenes are not examined in this paper.

Garnets from Eclogite Xenoliths vs Eclogite Garnets Included in Diamonds

As it is single garnet xenocrysts, not the polygranular eclogite xenoliths discussed above, that are typically employed in kimberlite and diamond exploration, compositional characteristics of single garnets alone must be considered. The high Na₂O content of garnet from diamond-bearing eclogites, and of eclogitic garnet inclusions in diamonds, is accompanied by high TiO₂ content (Danchin and Wyatt, 1979), a relationship seen in eclogitic garnet included in diamonds in Figure 7. This garnet inclusion population has been suggested as a useful "target" in diamond exploration (Fipke et al., 1989, 1995; Gumey and Moore, 1993; Gumey et al., 1993).

Comparison of compositions of eclogitic garnet inclusions in diamonds with garnets from diamond-bearing eclogites from individual kimberlites reveals substantial differences between the two types of garnet occurrences at some locations. In Figure 8 such comparisons are made for Roberts Victor, Orapa, and Sloan diamond inclusion eclogitic garnets and garnets from diamond eclogites. There is no overlap between the two suites at Roberts Victor and Sloan (although the Sloan diamond eclogite data base is very small), and at Orapa the two

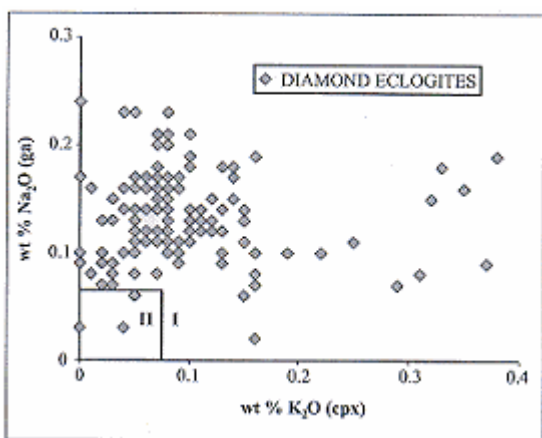


Fig. 6. Compositions of garnets and clinopyroxenes from diamond-bearing eclogites worldwide. Data from sources cited in Figure 8 and McCandless and Collins (1989), Taylor et al. (1996), Viljoen (1994), Sobolev (1977), Sobolev et al. (1994), Hills and Haggerty (1989), Jerde et al. (1993), Beard et al. (1996) and this paper. Group I vs Group II distinction is based on $K_{20} \geq 0.09$ wt% in clinopyroxene or $Na_{20} \sim 0.07$ wt% in garnet (after McCandless and Gurney [1989] and Gurney [1984] as discussed in the text).

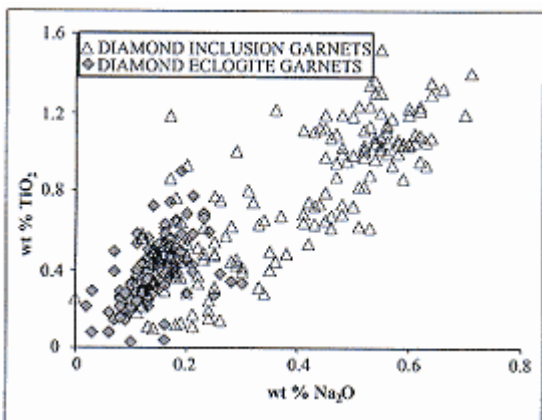


Fig. 7. Comparison of TiO₂ and Na₂O values of eclogite-suite garnets included in diamonds and garnets from diamondiferous eclogites. Data sources as in Figures 6 and 8 and additional garnets from diamond eclogites in Jacob et al. (1994).

populations differ, but overlap. In each example, garnets from diamond eclogites have lower TiO₂ and/or Na₂O contents than eclogitic garnets included in diamonds from the same kimberlite. A similar relationship was documented by Taylor et al. (1996) in three samples from the Udachnaya Mine. They showed that within individual diamond eclogite xenoliths, garnets included in diamonds had higher Na₂O and TiO₂ than did garnets in the host eclogite. Differences in other elements also exist (e.g., at Roberts Victor, diamond inclusion garnets have MnO > 1 wt%, whereas garnets from diamond eclogites have < 0.5 wt% MnO).

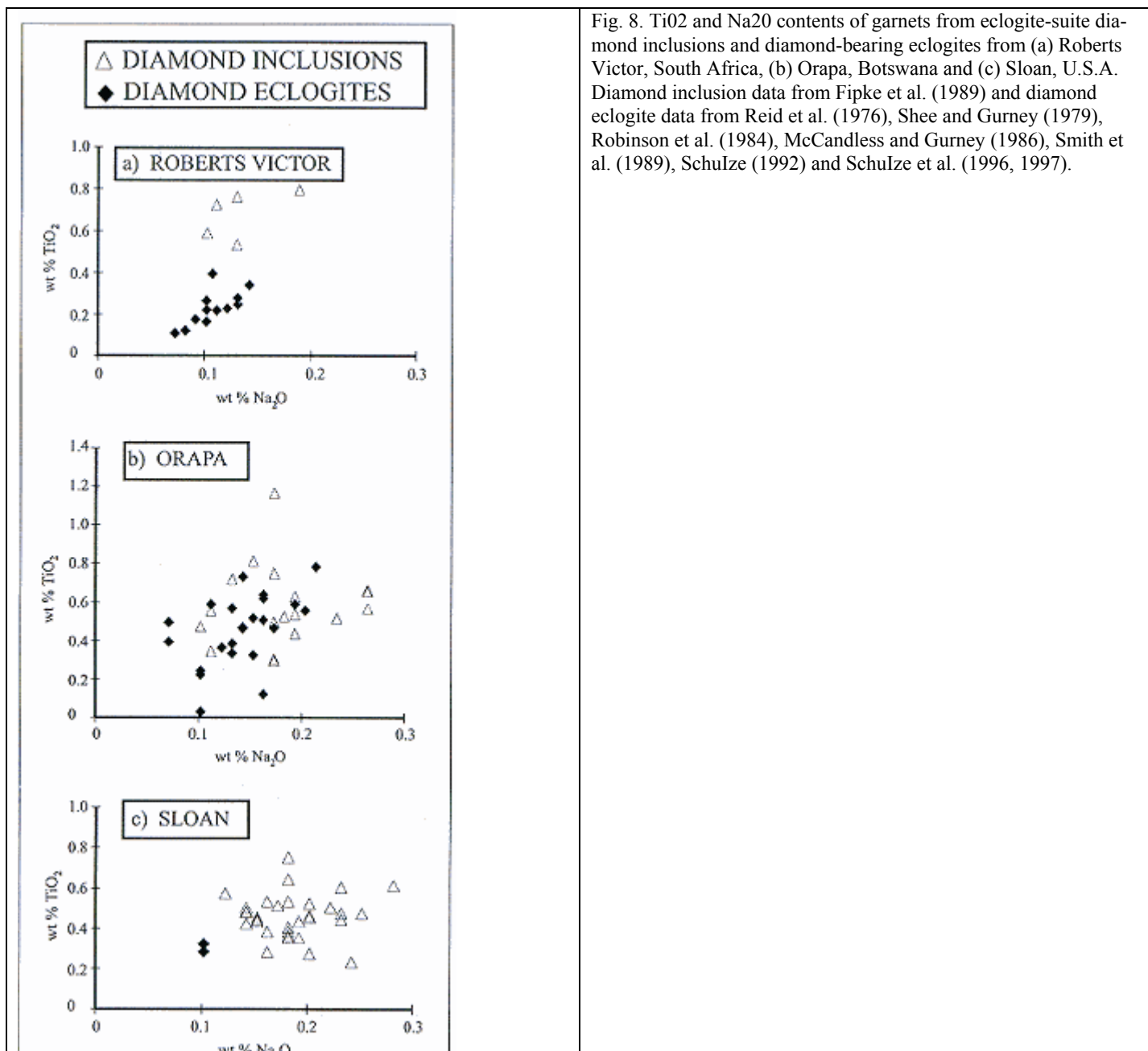


Fig. 8. TiO₂ and Na₂O contents of garnets from eclogite-suite diamond inclusions and diamond-bearing eclogites from (a) Roberts Victor, South Africa, (b) Orapa, Botswana and (c) Sloan, U.S.A. Diamond inclusion data from Fipke et al. (1989) and diamond eclogite data from Reid et al. (1976), Shee and Gurney (1979), Robinson et al. (1984), McCandless and Gurney (1986), Smith et al. (1989), Schulze (1992) and Schulze et al. (1996, 1997).

Chemical differences between the two populations at individual kimberlites suggest that the chemical signatures of the diamond inclusion garnets represent earlier P-T-X equilibration conditions corresponding to diamond formation conditions, preserved inside the diamonds, whereas the host minerals to the diamonds have re-equilibrated in the open system of the surrounding mantle in response to changing conditions since the time of diamond formation. Similar diamond inclusion-xenolith changes have been inferred for chromites and garnets of the peridotite diamond suite (Griffin et al., 1993; Gurney and Zweistra, 1995; Schulze, 1996).

With such differences in mind, the importance of using the compositions of garnets from diamondiferous eclogites as an exploration target instead of those of diamond inclusion garnets becomes clear. Garnet xenocrysts with compositions corresponding to those observed as inclusions in diamonds may not exist in a sample population of eclogite garnet xenocrysts. TiO₂-Na₂O variations of garnets from diamondiferous eclogites are shown in Figure 7, compared to eclogite-suite garnets included in diamonds. Note that the compositions of diamond eclogite garnets are very restricted relative to those of eclogitic garnets included in diamonds. Most garnets from diamond eclogites have values of Na₂O < 0.2 wt%, in contrast Na₂O values for diamond inclusion garnets of up to 0.7 wt% in Figure 7 (or even higher, Gurney and Moore, 1993).

Although the interpretation above is that both suites (garnets in diamonds and garnets in eclogite hosts to diamonds) have a common origin, differing, at present, due to post-diamond re-equilibration of the unencapsulated eclogite minerals, Robinson et al. (1984) suggested that the two suites have different origins, accounting for their different compositions. The differences of interpretation are immaterial as far as use in exploration is concerned. The grain size in typical exploration samples implies derivation from relatively coarse-grained xenoliths (>0.25 mm), in contrast to grains tens to hundreds of microns in diameter that are typical of diamond inclusion minerals.

Eclogitic Garnets vs Cr-poor Megacryst Garnets

Garnets from the Cr-poor megacryst suite also have significant Na₂O and TiO₂ contents, with most examples having ~10.07 wt% Na₂O (Gurney and Zweistra, 1995; Schulze, 1995) required for Group 1 eclogite classification, although they are unrelated to eclogites. Simplistic application in diamond exploration of the "high Na₂O in orange garnet" approach could be very misleading, as it could result in mistakenly identifying Cr-poor megacryst garnets as Group 1 eclogite garnets. Although both types of garnets are kimberlite indicator minerals, and the typical abundance of Cr-poor megacryst suite garnets in kimberlites makes them the dominant orange mantle-derived garnet in most kimberlites, the Cr-poor megacryst suite garnets have no genetic connection with diamonds (Fipke et al., 1995; Gurney and Zweistra, 1995). Most Cr-poor garnet megacrysts (and xenocrysts derived from them) can be distinguished from eclogite gar-

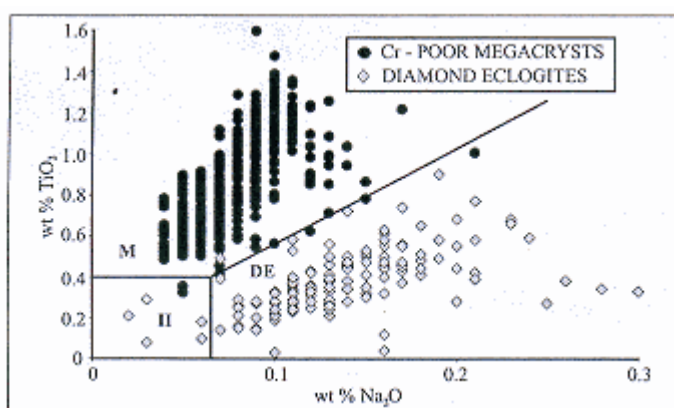


Fig. 9. Comparison of TiO₂ and Na₂O contents of Cr-poor megacryst garnets and garnets from diamondiferous eclogites. Diamondiferous eclogite (DE), Cr-poor megacryst (M) and Group 11 eclogite (11) fields are discussed in the text. Data sources as in Figures 2, 6, 7, and 8.

nets using additional chemical criteria, however, as illustrated on a TiO₂-Na₂O diagram in Figure 9. The three generalized fields shown on this diagram correspond to garnets from Cr-poor megacrysts (M), diamond-bearing eclogites (DE) and Group 11 eclogites (11). Although Group 11 data are not shown, the field outlined here is consistent with their typically low Na₂O and TiO₂ garnets (Gurney, 1984; Smyth and Caporuscio, 1984; McCandless and Gurney, 1989) and very few diamondiferous eclogites have Na₂O and TiO₂ contents so low as to allow them to be "misclassified" on this generalized diagram. Although some Group 1 eclogites have TiO₂-rich garnets corresponding to the megacryst field in Figure 9 (e.g., Kaalvallei), such Ti-rich Group 1 eclogites are not known to contain diamond.

Abundance of Diamonds in Diamond-bearing Eclogites

Diamond-bearing xenoliths are rare and, in contrast to the peridotite-suite dominated diamond inclusion population, most diamondiferous xenoliths are eclogites. Many diamondiferous eclogites are extraordinarily rich in diamonds (Robinson, 1979; Robinson et al., 1984; Schulze, 1992). A compilation (Schulze, 1992) showed that the average diamond grade of such eclogites was 14 000 carats per ton, approximately two orders of magnitude greater than known diamond-bearing peridotites (125 carats per ton). New data for diamond grades of 13 diamondiferous eclogites from the Udachnaya Mine are presented in Table 2. These eclogites have an average diamond grade of approximately 28 000 carats per ton, increasing the world average for diamondiferous eclogites (21 samples) to a grade of approximately 23 000 carats per ton (data from Robinson, 1979; Robinson et al., 1984; Schulze, 1992; Schulze et al., 1996; Table 2).

Disaggregation of relatively small quantities of diamond-rich eclogite could easily provide economic quantities of diamonds in a kimberlite, yet such a process would also provide relatively small quantities of xenocrystal garnet (and clinopyroxene) indicative of the origin of the diamonds. An eclogite with 0.5 wt% diamond (25 000

carats/ton) would yield only about 100 garnets for every diamond, on disaggregation, assuming a uniform grain size. Such xenocrysts would be diluted in the host kimberlite by other mantle xenocrysts not from diamondiferous eclogites, and thus might not show up in significant quantities in the kimberlite concentrate (as shown below for Sloan and Premier), much less be found in dispersal indicator mineral trains in the sedimentary environment.

Abundance of Eclogitic and Megacryst Garnets in Indicator Mineral Surveys

Results from many recent kimberlite and diamond exploration programs and regional indicator mineral surveys have indicated far greater eclogite:peridotite garnet values than would be expected from kimberlite sources, considering the data above for garnet populations in kimberlites, and typically a virtual absence of Cr-poor megacryst suite garnets. For example, Morton et al. (1993) reported locations at which eclogitic garnets were found, in the absence of Cr-pyropes, among Alberta - exploration indicator mineral suites. In a survey of Alberta indicator minerals, Dufresne et al. (1996) reported 104 "kimberlitic" garnets (dominantly Cr-pyropes and including megacryst-derived Ti-pyropes) but 170 "eclogitic" garnets. In addition, Simpson (1993) concluded that approximately 27% of garnets from exploration samples in Saskatchewan were eclogite-derived, and, in the same region, Swanson and Gent (1993) reported an eclogite:peridotite garnet value of approximately 30:70. Garnets that could be classified as derived from the Cr-poor megacryst suite (typically in Groups 1 and 2 of the Dawson and Stephens [1975] classification) constituted only trace amounts of the populations in the Simpson (1993) and Swanson and Gent (1993) studies, although they reported substantial numbers of "G5" garnets. These "G5" garnets are almandines (classified using the Dawson and Stephens (1975) classification) and ascribed by Simpson (1993) and Swanson and Gent (1993) to eclogite or crustal sources, implying that garnets from the two sources could not be distinguished from each other based on composition. Garrett and Thorleifson (1996) also reported unusually high eclogite and "near eclogite" (an unexplained term) garnet abundances of **23%, but**, in contrast to most studies, recognized a substantial (and reasonable) proportion of garnets likely to be derived from the Cr-poor megacryst suite (30% of garnets analyzed).

The unexpectedly high numbers of garnets purported to be of "eclogitic" affinity in these studies suggests that many garnets of crustal derivation have been mistakenly classified as eclogite garnets. For example, over 75% of garnets classified as "eclogitic" by Dufresne et al. (1996) would be assigned a crustal origin based on FeO contents of >22% (Fig. 5) and low TiO₂ values. Similarly, inclusion of Group 5 almandines with garnets considered to be derived from mantle eclogites is unlikely to be well-founded, as the most abundant crustal garnets (those from amphibolite-grade pelitic and basic schists and gneisses) typically correspond to Dawson and Stephen's (1975) Group 5, whereas few mantle eclogite garnets would be so classified (Schulze, 1993b). Most garnets used to define Group 5 (Dawson and Stephens, 1975) are now known to be crustal garnet xenocrysts or from anomalous low-temperature metamorphic eclogites, both quite unlike typical mantle eclogites (Schulze, 1993b). A small population of garnets derived from a Group I kimberlite, but collected in the secondary (sedimentary) environment is likely to have very few, if any, eclogitic garnets. Purple or red Cr-pyropes should dominate the garnet population. Even if, in the source kimberlite, purple Cr-pyropes are subordinate to orange mantle-derived garnets (from eclogites and megacrysts), they are not likely to be less abundant than orange *kimberlite-derived* garnets by a factor of more than two or three, and these situations would be uncommon. Furthermore, in the orange garnet population, garnets from the Cr-poor megacryst suite should outnumber those from eclogites by approximately an order of magnitude in most cases (excluding Group 11 kimberlites). In most (and perhaps all) situations, considering known garnet xenocryst abundances in kimberlites, it would not be reasonable to expect that a kimberlite could be discovered by tracing orange garnets, thought to be "eclogitic", in the absence of purple Cr-pyropes in exploration samples. Even in some kimberlites in which diamond populations are dominated by eclogite-derived diamonds, xenocrysts of eclogitic garnets can be rare. At the Sloan kimberlite Schulze (1993a) found only 8 of 138 garnet xenocrysts to be eclogitic and Fipke et al. (1989, 1995) documented only 11 of 172 Sloan garnets as eclogite-derived. At the Premier Mine no garnets of eclogite affinity were found in a suite of 132 garnet xenocrysts from heavy mineral concentrate (Schulze, -1994). Such unexpectedly low numbers of eclogitic garnets and the apparent discrepancies with the diamond populations may be due to richly diamondiferous eclogite yielding abundant diamonds yet low volumes of garnet, upon disaggregation.

Conclusions

Garnets from diamond eclogites have chemical characteristics that are useful in exploration for diamond-bearing kimberlites, in much the same way as peridotite-derived low-Ca Cr-pyropes and Mg- and Cr-rich chromites are used. Application of these characteristics is not as straightforward as in the pyrope and chromite situation, however, due to potential confusion of eclogite garnets with similar garnets from other sources and a typically low abundance of eclogitic garnets in kimberlite. Chemical characteristics such as lower FeO contents, and moderate TiO₂ coupled with elevated Na₂O contents, allow discrimination of orange eclogite garnets (potentially derived from diamondiferous samples) from orange crustal and Cr-poor megacryst garnets, respectively. These, and other, chemical screens have been suggested in this paper to assist in the classification and interpretation of orange garnets obtained in diamond exploration programs. The proposed boundaries could shift if larger, or alternate, data bases were used to define the

fields, but such shifts are likely to be small and should not significantly affect the present garnet classification.

Worldwide, eclogite garnet xenocrysts are typically uncommon in kimberlite heavy mineral concentrates, and thus they should not be expected to be encountered frequently, or in abundance, in indicator mineral exploration programs, especially in distal portions of indicator mineral trains where few kimberlite indicator minerals occur. This should be true even if the diamond population of the source kimberlite is dominated by eclogite-suite diamonds. Such a kimberlite can still be traced, however, utilizing Cr-pyropes, Cr-poor megacryst suite garnets, chromites and ilmenites if it is not virtually barren of all indicator minerals. The fact that it is diamondiferous should be discernible using the compositions of the pyropes and chromites, as all diamondiferous kimberlites apparently contain low-Ca Cr-pyropes, even those such as Orapa that are dominated by eclogitic diamonds (Gurney, 1984; Gurney and Zweistra, 1995). As disaggregation of diamond eclogite may yield as little as only 100 garnet xenocrysts for each diamond, usefulness of these garnets in a kimberlite evaluation program may need to be restricted to advanced stages of the evaluation of a pipe (when abundant material is

available), rather than in the exploration stage. Conversely, the explorationist must be aware of the potential significance of eclogite-derived garnets if they are encountered in an exploration program.

Acknowledgments

I thank Warren Boyd who allowed access to some of the Udachnaya eclogites, and Ulrich Krull, Associate Dean of Sciences, Erindale College and John Westgate of the Geology Department, University of Toronto who helped to obtain other Udachnaya samples. Members of De Beers Geology Department, Anglo American Research Laboratories and Howard Coopersmith are thanked for providing assistance that allowed collection of many of the megacryst samples, and Simon Shee and Keith Whitelock are thanked for providing others. Discussions with Stu Averill, Herb Helmstaedt and Howard Coopersmith and reviews by Stu Averill, Bruce Kjarsgaard, Tom McCandless, George Read, J. Ridley and R. Ramsay helped to improve the manuscript. Dragan Andjelkovic is thanked for assistance in producing the figures, Claudio Cermignani for assistance with the electron microprobe, and Jennifer Wismiewski for help with manuscript preparation. Financial support was provided by NSERC.

Appendix

New data in this study for diamond eclogites and Cr-poor garnet megacrysts were obtained by electron microprobe analysis using a Cameca SX-50 microprobe and wavelength dispersive methods and PKP corrections in the Department of Geology at the University of Toronto. Counting times on peaks were between 30 and 60 seconds per element, with 60 seconds used for K in clinopyroxene and Na

in garnet to achieve high precision and low detection limits needed for eclogite classification. The eclogite data in Table 1 are averages of 3 to 5 analyses each of garnet and clinopyroxene, made on tiny fragments removed from the xenoliths.

Few garnet megacryst data are available in the published literature, so to enlarge the database for this potential indicator mineral, 393 new analyses are provided in Table 3, representing a variety of kimberlites, worldwide. Cr-poor garnet megacrysts were analyzed as chips in grain mount with 2 to 5 points per sample. The tabulated mineral chemical data that form the data base of this paper can be downloaded from the Internet by connecting to the University of

Toronto Department of Geology's WWW server at URL [HTTP://www.geology.utoronto.ca](http://www.geology.utoronto.ca). Follow the link to "Software and Data Sets from Our Researchers."

References

- ATER, P.C., 1982. Petrology and Geochemistry of Mantle Eclogite Xenoliths from Colorado-Wyoming Kimberlites. M.S. thesis, Colorado State University, 237 p.
- AZOR, A. and BALI-tVRE, 1997. Low-pressure metamorphism in the Sierra Albarrana Area (Variscan Belt, Iberian Massif). *Journal of Petrology*, 38, p. 35-64.
- BEARD, B.L., FRARACCI, KX, TAYLOR, L.A., SNYDER, G.A., CLAYTON, R.A., MAYEDA, T.K. and SOBOLEV, NY, 1996. Petrography and geochemistry of eclogites from the Mir kimberlite, Yakuria, Russia. *Contributions to Mineralogy and Petrology*, 125, p. 293-310.
- BEGIN, N.J. and PATTISON, D.R.M., 1994. Metamorphic evolution of granulites in the Minto Block, northern Quebec: Extraction of peak P-T conditions taking account of late Fe-Mg exchange, *Journal of Metamorphic Geology*, 12, p. 411-428.
- BOYD, ER. and NIXON, P.H., 1978. Ultramafic nodules from the Kimberley pipes. *Geochimica et Cosmochimica Acta*, 42, p. 1267-1282 (Appendix).
- COX, K.G., GURNEY, J.J. and HARTE, B., 1973. Xenoliths from the Matsoku Pipe. In *Lesotho Kimberlites. Edited by P.H. Nixon. Lesotho National Development Corp., Maseru*, p. 76-92, plus Appendix.
- DANCHIN, R.V. and WYATT, B.A., 1979. Statistical cluster analysis of garnets from kimberlites and their xenoliths. *Kimberlite Symposium 11, Cambridge*, p. 22-27.
- EGGLER, D.H., McCALLUM, M.E. and SMITH, C.B., 1979. Megacryst assemblages in kimberlites from northern Colorado and southern Wyoming. *In The Mantle Sample: Inclusions in Kimberlites and Other Volcanics. Edited by ER. Boyd and H.O.A. Meyer. American Geophysical Union, Washington*, p. 213-226.
- FIPKE, C.E., GURNEY, LL, MOORE, R.O. and NAS SICHUCK, W.W., 1989. The development of advanced technology to distinguish between diamondiferous and barren diatremes. *Geological Survey of Canada Open File 2124*, 621 p.
- FIPKE, C.E., GURNEY, J1 and MOORE, R.O., 1995. Diamond exploration techniques emphasizing indicator mineral geochemistry and Canadian examples. *Geological Survey of Canada Bulletin 423*, p. 86.
- FITZSIMONS, I.C.W., 1996. Metapelitic migmatites from Brattstrand Bluffs, East Antarctica - Metamorphism, melting and exhumation of the mid crust. *Journal of Petrology*, 37,p. 395-414.
- FITZSIMONS, I.C.W. and HARLEY, S.L., 1994. The influence of retrograde cation exchange on granulite P-T estimates and a convergence technique for the recovery of peak metamorphic conditions. *Journal of Petrology*, 35, p. 543-576.
- FORD, F.D., 1987. Petrology and Geochemistry of Xenoliths from the Blaauwboosch Kimberlite Pipe, R.S.A. B.Sc. thesis, Queen's University, 86 p.
- GARRETT, R.G. and THORLIEFSON, L.H., 1996. Kimberlite indicator mineral and soil geochemical reconnaissance of the Canadian Prairie region. *In Searching for Diamonds in Canada. Edited by A.N. LeCheminant, D.G. Richardson, R.N.W. DiLabio and K.A. Richardson. Geological Survey of Canada, Open File 3228*, p. 205-211.
- GORDON, T.M., GHENT, E.D. and STOUT, MX, 1991. Algebraic analysis of the biotite-sillimanite isograd in the File Lake area, Manitoba. *Canadian Mineralogist*, 29, p. 673-686.
- GORDON, T.M., ARANOVICH, L. YA. and FED'KIN, V.V., 1994. Exploratory data analysis in thermobarometry: An example from the Kiseynew Sedimentary Gneiss Belt, Manitoba, Canada. *American Mineralogist*, 79, p. 973-982.
- GRIFFIN, W.L. and RYAN, C.G., 1995. Trace elements in indicator minerals: Area selection and target evaluation in diamond exploration. *Journal of Geochemical Exploration*, 53, p. 311-337.
- GRIFFIN, W.L., SOBOLEV, N.V., RYAN, C.G.,

- DAWSON J.13. and STEPHENS, W.E., 1975. Statistical classification of garnets from kimberlites and associated xenoliths. *Journal of Geology*, 83, p. 589-607.
- DE BRUIN, D., 1991. The Megacryst Suite from the Schuller Kimberlite, South Africa. Ph.D. thesis, University of Cape Town, 250 p.
- DUFRESNE, M.B., ECCLES, D.R., MCKINSTRY, B., SCHMITT, D.R., FENTON, M.M., PAWLOWICZ, LG. and EDWARDS, W.A.D., 1996. The diamond potential Of Alberta. *Alberta Geological Survey Bulletin* 63, 158 p.
- GURNEY, J1, 1989. Diamonds. In *Kimberlites and Related Rocks. Vol. 2: Their Mantle/Crust Setting, Diamonds and Diamond Exploration. Edited by J. Ross.* Blackwell, Carlton, Australia, p. 935-965.
- GURNEY, J.J. and KIRKLEY, M.B., 1996. Kimberlite dyke mining in South Africa. *Africa Geoscience Review*, 3, p. 191-201.
- GURNEY, J1 and MOORE, R.O., 1993. Geochemical correlations between kimberlitic indicator minerals and diamonds. In *Diamonds: Exploration, Sampling and Evaluation. Prospectors and Developers Association of Canada Short Course*, p. 361-377.
- GURNEY, J.J. and SWITZER, G.S., 1973. The discovery of garnets closely related to diamonds in the Finsch pipe, South Africa. *Contributions to Mineralogy and Petrology*, p. 103-116,
- GURNEY, J1 and ZWEISTRA, R, 1995. The interpretation of the major element compositions of mantle minerals in diamond exploration. *Journal of Geochemical Exploration*, 53, p. 293-309.
- GURNEY, LL, JAKOB, W.R.O. and DAWSON, J.13., 1979. Megacrysts from the Monastery kimberlite pipe, South Africa. In *The Mantle Sample: Inclusions in Kimberlites and Other Volcanics. Edited by F.R. Boyd and H.O.A. Meyers.* American Geophysical Union, Washington, p. 227-243.
- GURNEY, J1, HELMSTAEDT, H. and MOORE, R.O., 1993. A review of the use and application of mantle mineral geochemistry in diamond exploration. *Pure and Applied Chemistry*, 65, p. 2423-2442.
- HALL, D.C., 1985. The Petrology of Xenoliths from the Orapa AKI Kimberlite Pipe, Botswana. M.Sc. thesis, Queen's University, 186 p.
- HARTEL, T.H.D. and PATTISON, D.R.M., 1996. Genesis of the Kapuskasing (Ontario) migmatitic mafic granulites by dehydration melting of amphibolite: The importance of quartz to reaction progress. *Journal of Metamorphic Geology*, 14, p. 591-611.
- HATTON, C.J., 1977. The Geochemistry and Origin of Xenoliths from the Roberts Victor Mine. Ph.D. thesis, University of Cape Town, 179 p.
- HAWTHORNE, J.13., GURNEY, LL, HARRIS, JW. and RICKARD, R.S., 1978. Inclusions in diamonds from South Africa. Extended Abstracts, IX Meeting, International Mineralogical Association, Novosibirsk, Siberia.
- HILLS, DY and HAGGERTY, S.E., 1989. Petrochemistry of eclogites from the Koidu kimberlite complex, Sierra Leone. *Contributions to Mineralogy and Petrology*, 103, p. 397-422.
- JACOB, D., JAGOUTZ, E., LOWRY, D., MATTEY, D. and KU13RJAVTSEVA, G., 1994. Diamondiferous eclogites from Siberia: Remnants of Archean oceanic crust. *Geochimica et Cosmochimica Acta*, 58, p. 5191-5207.
- JERDE, E.A., TAYLOR, L.A., CROZA4 G., SOBOLEV, NX and SOBOLEV, VX, 1993. Diamondiferous eclogites
- POKHMENKO, N.P., WIN, T.T. and YEFIMOVA, Y., 1993. Trace elements in garnets and chromites: Diamond formation in the Siberian lithosphere. *Lithos*, 29, p. 235-256.
- GUIRAUD, M., POWELL, R. and COTTIN, L-Y., 1996. Hydration of orthopyroxene-cordierite-bearing assemblages at Laouni, Central Hoggar, Algeria. *Journal of Metamorphic Geology*, 14, p. 467-476.
- GURNEY, Jj., 1984. A correlation between garnets and diamonds. In *Kimberlite Occurrence and Origin: A basis for Conceptual Models in Exploration. Edited by LE. Glover and P.G. Harris.* University of Western Australia Publication 8, p. 376-383.
- KNUDSEN, T.-L., 1996. Petrology and geothermobarometry of granulite facies metapelites from the Hisoy-Torungen area, south Norway: New data on the Sveconorwegian P-T-t path of the Bamble sector. *Journal of Metamorphic Geology*, 14, p. 267-287.
- KRYZA, R., PIN, C. and VIE1-ZEUF, D., 1996. High-pressure granulites from the Sudetes (south-west Poland): Evidence of crustal subduction and collisional thickening in the Variscan Belt. *Journal of Metamorphic Geology*, 14, p. 531-546.
- LUCAS, H., RAMSAY, R.R., HALL, A.E., SMITH, C.B. and SOBOLEV, NX, 1989. Garnets from Western Australian kimberlites and related rocks. In *Kimberlites and Related Rocks. Vol. 2: Their Mantle/Crust Setting, Diamonds and Diamond Exploration. Edited by J. Ross.* Blackwell, Carlton, Australia, p. 809-819.
- MacGREGOR, I.D. and CARTER, LL., 1970. The chemistry of clinopyroxenes and garnets of eclogite and peridotite xenoliths from the Roberts Victor Mine, South Africa. *Physics of Earth and Planetary Interiors*, 3, p. 391-397.
- McCANDLESS, T.E. and COLLINS, D.S., 1989. A diamond graphite eclogite from the Sloan 2 kimberlite, Colorado, U.S.A. In *Kimberlites and Related Rocks. Vol. 2: Their Mantle/Crust Setting, Diamonds and Diamond Exploration. Edited by J. Ross.* Blackwell, Carlton, Australia, p. 1061-1069.
- McCANDLESS, T.E. and GURNEY, LL, 1986. Sodium in garnet and potassium in clinopyroxene: Criteria for classifying mantle eclogites. University of Cape Town, Kimberlite Research Group, Data Appendix, Internal Report 10, 60 p.
- McCANDLESS, T.E. and GURNEY, LL, 1989. Sodium in garnet and potassium in clinopyroxene: Criteria for classifying mantle eclogites. In *Kimberlites and Related Rocks. Vol. 2: Their Mantle/Crust Setting, Diamonds and Diamond Exploration. Edited by J. Ross.* Blackwell, Carlton, Australia, p. 827-832.
- MOORE, R.O., 1986. A Study of the Kimberlites, Diamonds and Associated Rocks and Minerals from the Monastery Mine, South Africa. Ph.D. thesis, University of Cape Town, 359 p.
- MORTON, R.D., STEWART, LR, BALE, W.C. and DAY, R.C., 1993. A review of diamond occurrences and potentials in Alberta. In *Mid-continent diamonds. Edited by K.RE. Dunne and B. Grant.* Geological Association of Canada, Mineral Deposits Division, Symposium Volume, p. 101-104.
- NIXON, RH., 1995. A review of mantle xenoliths and their role in diamond exploration. *J. Geodynamics*, 20, p. 305-329,
- NIXON, P.H. and BOYD, FK, 1973a. The discrete nodule (megacryst) association in kimberlites from northern Lesotho. In *Lesotho Kimberlites. Edited by RH. Nixon.* Lesotho National Development Corp., Maseru, p. 67-75.
- NIXON, P.H. and BOYD, FK, 1973b. Petrogenesis of the granular and sheared ultrabasic nodule suite in kimberlites, In *Lesotho Kimberlites. Edited by P.H. Nixon.* Lesotho

- from Yakutia, Siberia: Evidence for a diversity of pro-toliths. *Contributions to Mineralogy and Petrology*, 114, p. 189-202.
- PATTISON, D.R.M., 1991. Infiltration-driven dehydration and anatexis in granulite facies metagabbro, Grenville Province, Ontario, Canada. *Journal of Metamorphic Geology*, 9, p. 315-332.
- PATTISON, D.R.M. and BTGIN, N.J., 1994. Zoning patterns in orthopyroxene and garnet in granulites: Implications for geothermometry. *Journal of Metamorphic Geology*, 12, p. 387-410.
- PATTISON, D.R.M., CARMICHAEL, D.M. and ST-ONGE M.R., 1982. Geothermometry and geobarometry applied to Early Proterozoic "S-type" granitoid plutons, Wopmay Orogen, Northwest Territories, Canada. *Contributions to Mineralogy and Petrology*, 79, p. 394-404.
- PERCIVAL, J., 1981. Geological evolution of part of the central Superior Province based on relationships among the Abitibi and Wawa sub-provinces and the Kapuskasing Structural Zone. Ph.D. thesis, Queen's University, 300 p.
- REID, A.M., BROWN, R.W., DAWSON, J.13., WHITFIELD, G.G. and SIEBERT, J.C., 1976. Garnet and pyroxene compositions in some diamondiferous eclogites. *Contributions to Mineralogy and Petrology*, 58, p. 203-220.
- ROBEY, J.V.A., 1981. Kimberlites of the Central Cape Province, R.S.A. Ph.D. thesis, University of Cape Town, 261 p.
- ROBINSON, D.N., 1979. Diamond and graphite in eclogite xenoliths from kimberlite. *In The Mantle Sample: Inclusions in Kimberlites and Other Volcanics. Edited by F.R. Boyd and H.O.A. Meyer.* American Geophysical Union, Washington, p. 50-58.
- ROBINSON, D.N., GURNEY, J.J. and SHEE, S.R., 1984. Diamond eclogite and graphite eclogite xenoliths from Orapa, Botswana. *In Kimberlites II: Their Mantle and Crust-mantle Relationships. Edited by J. Kornprobst.* Elsevier, Amsterdam, p. 11-24.
- SCHUTZE, D.J., 1982. The Petrology of Ultramafic Xenoliths from the Hamilton Branch Kimberlite Pipe, Elliott County, Kentucky. Ph.D. thesis, University of Texas at Dallas, 132 p.
- SCHULZE, D.J., 1987. Megacrysts from alkaline volcanic rocks. *In Mantle Xenoliths. Edited by R.H. Nixon.* Wylie, London, p. 433-451.
- SCHUTZE, D.J., 1989. Constraints on the abundance of eclogite in the upper mantle. *Journal of Geophysical Research*, 94, p. 4205-4212.
- SCHUTZE, D.J., 1992. Diamond eclogite from Sloan Ranch, Colorado, and its bearing on the diamond grade of the Sloan kimberlite. *Economic Geology*, 87, p. 2175-2179.
- SCHUTZE, D.J., 1993a. Garnet xenocryst populations in North American kimberlites. *In Diamonds: Exploration, Sampling and Evaluation. Prospectors and Developers Association of Canada Short Course*, p. 361-377.
- SCHUTZE, D.J., 1993b. Caution advised in interpreting garnet data in kimberlite search. *The Northern Miner*, 79, p. 4.
- SCHUTZE, D.J., 1994. Abundance and distribution of low-Ca garnet harzburgites in the subcratonic lithosphere of southern Africa. *In Kimberlites, Related Rocks and Mantle Xenoliths. Edited by H.O.A. Meyer and O. Leonardos.* Companhia de Pesquisa de Recursos Minerais, Special Publication I-A94, p. 327-335.
- SOBOLEV, N.X., 1977. Deep-seated inclusions in kimberlites and the problem of the composition of the upper mantle. National Development Corp., Maserti, p. 48-56.
- NYMAN, M.W., PATTISON, D.R.M. and GHENT, E.D., 1995. Melt extraction during formation of k-feldspar + sillimanite migmatites, west of Revelstoke, British Columbia. *Journal of Petrology*, 36, p. 351-372.
- SCHUTZE, D.J., 1995. A guide to the recognition and significance of kimberlite indicator minerals. *In Diamonds - Theory and Exploration, A "Hands-on" Short Course.* Geological Association of Canada, Cordilleran Section, Short Course 20, 39 p.
- SCHUTZE, D.J., 1996. Chromite macrocrysts from southern African kimberlites: Mantle xenolith sources and post-diamond re-equilibration. *Africa Geoscience Review*, 3, p. 203-216.
- SCHUTZE, D.J. and HELMSTAEDT, H., 1988. Coesite-sandine eclogites from kimberlite: Products of mantle fractionation or subduction? *Journal of Geology*, 96, p. 435-443.
- SCHUTZE, D.J., WIESE, D. and STEUDE, J., 1996. Abundance and distribution of diamonds in eclogite revealed by volume visualization of CT X-ray scans. *Journal of Geology*, 104, p. 109-114.
- SCHUTZE, D.J., VALLEY, J.W., VILJOEN, K.S., STIEFHOFER, J. and SPICUZZA, M., 1997. Carbon isotope composition of graphite in mantle eclogites. *Journal of Geology*, 105, p. 379-386.
- SHEE, S.R., 1978. The Mineral Chemistry of Xenoliths from the Orapa Kimberlite Pipe, Botswana. M.Sc. thesis, University of Cape Town, 148 p.
- SHEE, S.R. and GURNEY, J.J., 1979. The mineralogy of xenoliths from Orapa, Botswana. *In The Mantle Sample: Inclusions in Kimberlites and Other Volcanics. Edited by F.R. Boyd and H.O.A. Meyer.* American Geophysical Union, Washington, p. 37-49.
- SIMPSON, M.A., 1993. Kimberlite indicator minerals in southwestern Saskatchewan. *In Mid-continent diamonds. Edited by K.P.E. Dunne and B. Grant.* Geological Association of Canada, Mineral Deposits Division, Symposium Volume, p. 53-57.
- SKINNER, E.M.W., 1989. Contrasting Group I and Group 11 kimberlite petrography: Towards a genetic model for kimberlites. *In Kimberlites and Related Rocks, Vol. 1: Their Composition, Occurrence, Origin and Emplacement. Edited by J. Ross.* Blackwell, Carlton, Australia, p. 528-544.
- SMITH, C.B., 1977. Kimberlite and Mantle Derived Xenoliths at Iron Mountain, Wyoming. M.S. thesis, Colorado State University, 218 p.
- SMITH, C.B., 1983. Pb, Sr, and Nd isotopic evidence for sources of southern African Cretaceous kimberlites. *Nature*, 304, p. 51-54.
- SMITH, C.B., GURNEY, J.J., HARRIS, J.W., ROBINSON, D.N., SHEE, S.R. and JAGOUTZ, E., 1989. Sr and Nd isotope systematics of diamond-bearing eclogite xenoliths and eclogitic inclusions in diamond from southern Africa. *In Kimberlites and Related Rocks, Vol. 2: Their Mantle/Crust Setting, Diamonds, and Diamond Exploration. Edited by J. Ross.* Blackwell, Carlton, Australia, p. 853-863.
- SMYTH, J.R. and CAPORUSCIO, E., 1984. Petrology of a suite of eclogite inclusions from the Bobbejaan kimberlite: II. Primary phase compositions and origin. *In Kimberlites II: Their Mantle and Crust-mantle Relationships. Edited by J. Kornprobst.* Elsevier, Amsterdam, p. 121-131.
- TOLLO, R.P., 1982. Petrography and Mineral Chemistry of Ultramafic and Related Inclusions from the Orapa A/K-1

- American Geophysical Union, Washington, D.C., 279 p.
- SOBOLEV, N.X. and LAVRENTEV, Y.G., 1972. Isomorphous sodium admixture in garnets formed at high pressure. *Contributions to Mineralogy and Petrology*, 31, p. 1-12.
- SOBOLEV, N.V., LAVRENTEV, Y.G., POSPELOVA, N.P. and USOVA, L.X., 1973. Cr-rich garnets from kimberlites of Yakutia and their parageneses. *Contributions to Mineralogy and Petrology*, 40, p. 39-52.
- SOBOLEV, V.N., TAYLOR, L.A. and SNYDER, G.A., 1994. Diamondiferous eclogites from the Udachnaya kimberlite pipe, Yakutia. *International Geology Review*, 36, p. 42-64.
- SWANSON, F.J. and GENT, M.R., 1993. Results of reconnaissance diamond indicator mineral sampling, Saskatchewan. In *Mid-continent Diamonds*. Edited by K.P.E. Dunne and B. Grant. Geological Association of Canada, Mineral Deposits Division, Symposium Volume, p. 113-119.
- TAYLOR, L.A., SNYDER, G.A., CROZAZ, G., SOBOLEV, V.N., YEFIMOVA, E.S. and SOBOLEV, N.V., 1996. Eclogitic inclusions in diamonds: Evidence of complex mantle processes over time. *Earth and Planetary Science Letters*, 142, p. 535-551.
- THONI, M. and MILLER, C.H., 1996. Garnet Sm-Nd data from the Saualpe and the Koralpe (Eastern Alps, Austria): Chronological and P-T constraints on the thermal and tectonic history. *Journal of Metamorphic Geology*, 14, p. 453-466.
- Kimberlite Pipe, Botswana. Ph.D. thesis, University of Massachusetts, 203 p.
- VILJOEN, K.S., 1994. The Petrology and Geochemistry of a Suite of Mantle-derived Eclogite Xenoliths from the Kaalvallei Kimberlite, South Africa. Ph.D. thesis, University of Witwatersrand, 160 p.
- VILJOEN, K.S., ROBINSON, D.R., SWASH, R.M., GRIFFIN, W.L., OTTER, M.L., RYAN, C.G. and WIN, T.T., 1994. Diamond- and graphite-bearing peridotite xenoliths from the Roberts Victor kimberlite, South Africa. In *Kimberlites, Related Rocks and Mantle Xenoliths*. Edited by H.O.A. Meyer and O. Leonards. Companhia de Pesquisa de Recursos Minerais, Special Publication 11A, Rio de Janeiro, p. 285-303.
- WHITNEY, D.L., MECHUM, T.A., HUEI---NER, S.M. and DILEK, Y.R., 1996. Progressive metamorphism of pelitic rocks from protolith to granulite facies, Dutchess County, New York, USA: Constraints on the timing of fluid infiltration during regional metamorphism. *Journal of Metamorphic Geology*, 14, p. 163-181.
- WILLNER, A.P., ROTZLER, K. and MARESCH, W.V., 1997. Pressure-temperature and fluid evolution of quartzofeldspathic metamorphic rocks with a relic high-pressure, granulite-facies history from the Central Erzgebirge (Saxony, Germany). *Journal of Petrology*, 38, p. 307-336.
- YEFIMOVA, E.S. and SOBOLEV, N.V., 1977. Abundance of crystalline inclusions in diamonds of Yakutia. *Doklady Akademii Nauk SSSR*, 237, p. 1475-1478.