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MANTLE LITHOSPHERE BENEATH WYOMING BASED ON SLOAN AND KELSEY LAKE - I KIMBERLITE XENOCRYSTS

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MINERALOGY OF XENOCRYSTS

Megacrysts and xenocrysts and their intergrowths from two Paleozoic kimberlite pipes Sloan and Kelsey Lake-1 (KL-1) in northern Colorado were analyzed by EPMA and LAM ICP-MS in Analytic Centre IGM SB RAS. We also investigated a smaller number of xenocrysts from the Chicken Park and Iron Mountain kimberlites.

GARNETS from Sloan (Fig. 1a) mainly fall in the lherzolite field (Coopersmith et al., 2003) with up to 12.5 Wt % Cr_2O_3. Compared to the KL-1 garnets which reach 14 Wt Cr_2O_3 and show deviations to the harzburgite fields, this is less favorable for the diamond grade.

CR-DIOPSIDES from Sloan (Fig. 2) are less depleted but similar to those in the Daldyn field Siberia, (Fig. 2b), showing similar divisions into groups including sheared peridotites. Cpx from Sloan are divided into two groups corresponding to the lower and upper parts of the mantle sections. The KL-1 diopsides show a trend that is restricted in FeO with sharp growth of Al, Cr and Na together with Fe, typical for metasomatites and hybrid varieties from Alakit field, Yakutia (Ashchepkov et al., 2004).

CR-SPINELS from Sloan (Fig. 3a) form a straight peridotitic Cr-Al trend. The TiO_2, V_2O_3 and Cr_2O_3 increase together while NiO, ZnO and Nb_2O_3 decrease, indicating the greater influence of protokimberlite melt at the base of the SCLM and its differentiation to the top. Chromites from the KL-1 pipe coincide (Fig.4) with the Cr-rich part of the Sloan spinel trend showing dispersion of TiO_2.

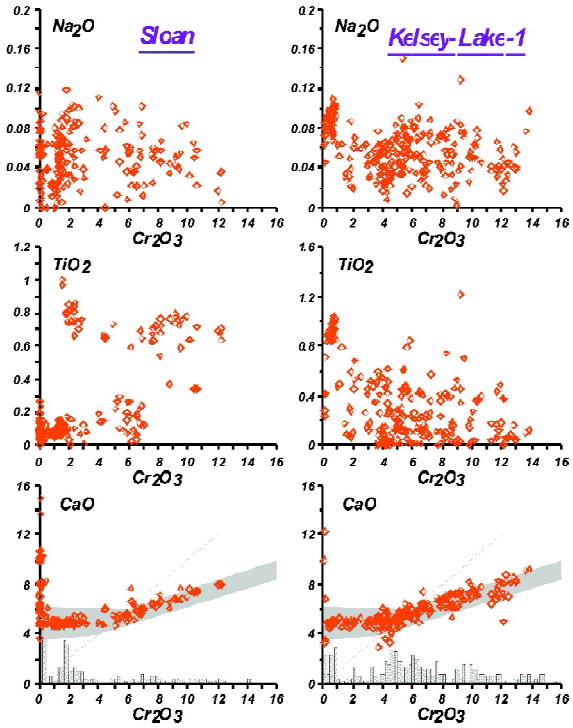

Fig.1. Variations of major element compositions from garnets from Sloan (a) and Kelsey Lake-1 (b). Pyrope compositions relate to lherzolitic field (Sobolev et al 1973) (up to 14 Wt % Cr_2O_3).

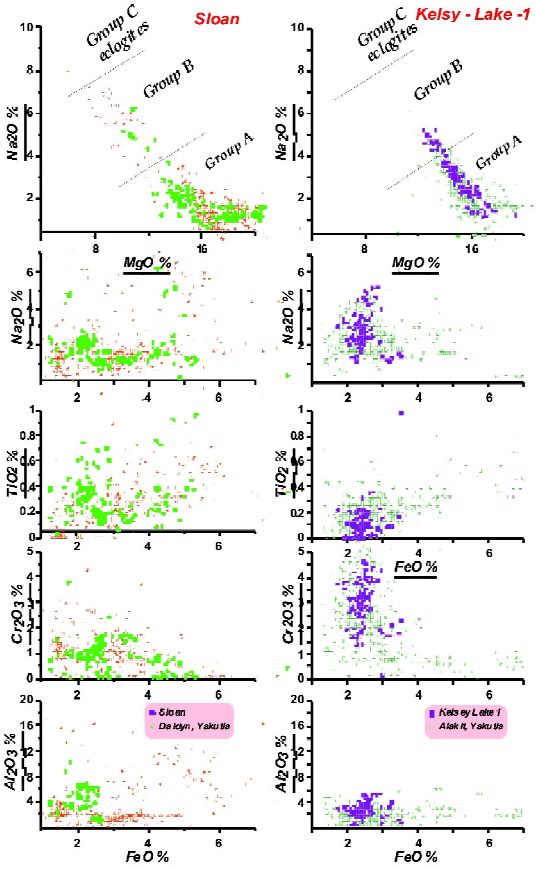

Fig.2. Variations of major element compositions of clinopyroxenes from Sloan (a) and Kelsey Lake 1 (b), in comparison with data for Daldyn and Alakit regions, Yakutia (Ashchepkov et al ., 2010)

ILMENITES from Sloan pipe (Fig. 4a) (TiO_2 from 56 to 44 Wt %) show a Cr-rich metasomatic branch with decreases in Al_2O_3 and FeO, and flat NiO. Cr_2O_3 shows a general increase to left part and Cr-low branch with low Cr and Al. The KL-1 ilmenite extended trend (Fig. 4b) (36-60% TiO_2) is dispersed because many ilmenites occur in intergrowths with exsolved rutile. Nevertheless the general tendencies are similar as for Sloan ilmenites showing enrichment in Cr and essential enrichment in MnO to 8 Wt %. Ilmenites from Chicken Park are mildly Mg- (8-10 Wt % MgO) and TiO_2-rich. They are slightly enriched in Al_2O_3 and show relatively low Ni content and highly varying V_2O_3.

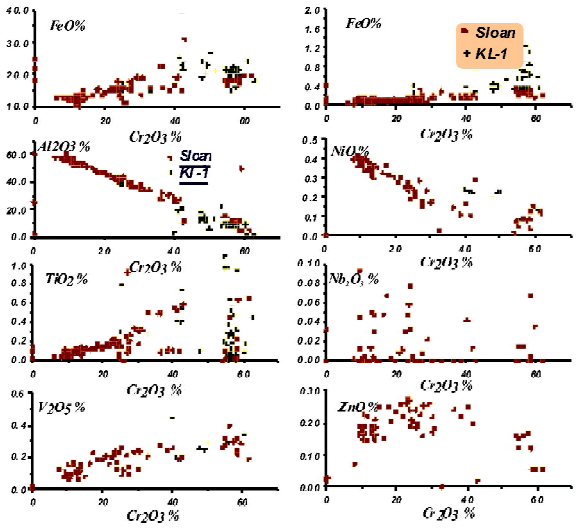

Fig.3 Variations of major element compositions for Cr- spinels from 1 Sloan and 2 KL-1 pipes

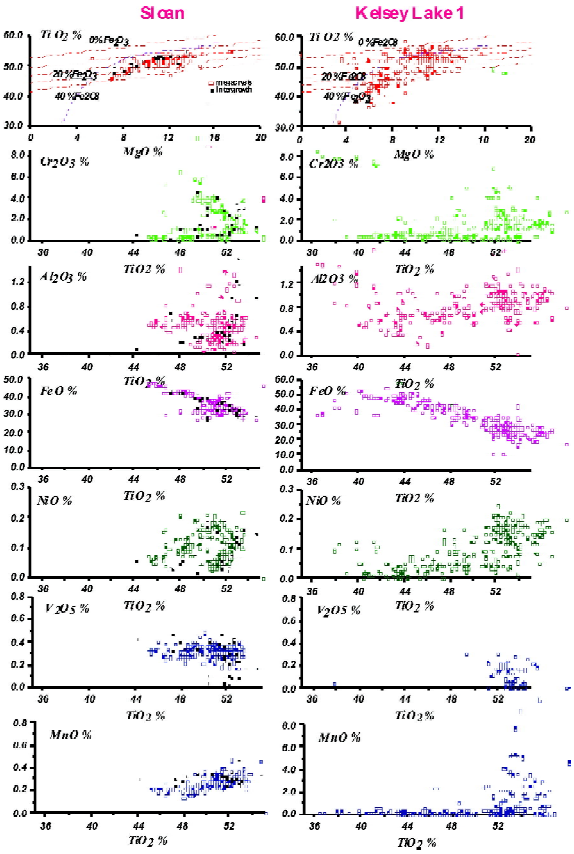

Fig.4 Variations of major element compositions of ilmenites from Sloan (a) (1 – xenocrysts 2- intergrowths) and Kelsey Lake (b)

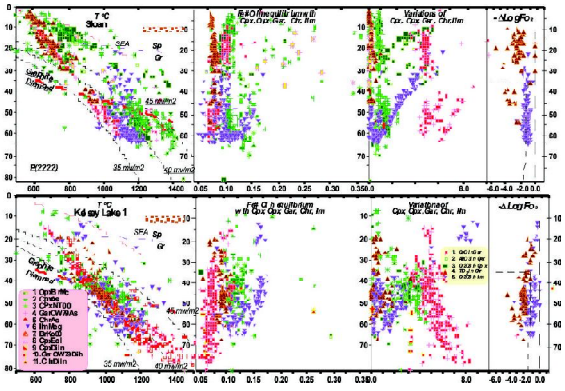

Fig.5. PTXFO$_2$ conditions for the new data and for all previous data set of deep seated inclusions from kimberlite pipes Symbols see (Ashchepkov et al ., 2010). Diamond inclusions (Schulze, 1992;Schulze et al., 2008). Symbols see Fig 5.

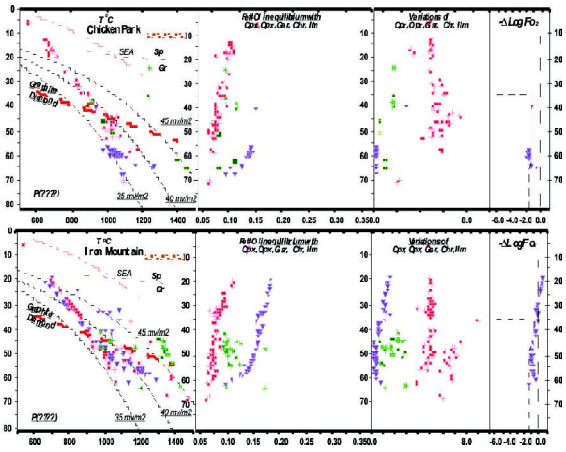

Fig.6. PTXFO$_2$ diagrams for the Vendian Chicken Park and Ordovician Iron Mountain pipes (Data from Griffin et al., 2004; Schulze et al ., 1995a; McCallum & Eggler, 1976; 1979). Symbols see Fig 5.

THERMOBAROMETRY AND RECONSTRUCTIONS OF MANTLE SECTIONS.

The subcratonic lithospheric mantle (SCLM) structure beneath the Sloan and Kelsey Lake kimberlites has been reconstructed using xenocrysts (~2000 analyses made in IGM, Novosibirsk) and monomineral methods described in Ashchepkov et al. (2010) which give close PT estimates to those obtained by the best methods (Brey & Kohler, 1990; Nimis & Taylor, 2000; McGregor, 1974).

The SCLM beneath Sloan pipe is divided to lower and upper parts at 40-30 kbar by a layer traced by Opx, omphacites (6 wt% Na_2O), low-Cr CPx and Cr ilmenites and diopsides from metasomatitic veins. In the lower part PT for lherzolitic garnets enriched in TiO_2 trace 37 mw/m^2 geotherm to SCLM base (75-60 kbar) showing the inflection (Nixon, Boyd,1973). Two advective branches rising from the base are marked by Cr-diopsides of sheared type. PT estimates for ilmenites and Ti- garnets reflect PT fractionation of protokimberlites (Fe#=17). Metasomatic veins with ilmenites show a stepped Cr_2O_3 rise (Fe# = 12) formed at lower temperatures but higher then fresh peridotitic (Fe#~ 8-10). The deeper Cr-spinels show TiO_2 and NiO contents decreasing to the top of the SCLM, also influenced by melts. The upper level < 30 kbar shows three PT paths: the hottest for Opx and Fe-Cpx, lower for garnets and Cpx and the lowest for Sp, Cpx and Gar with Fe#~9- 11 correspondingly. The latter are Sp lherzolites.

The lower temperature mantle sequence beneath KL-1 relates to < 35 mw/m^2 geotherm. HT branches for Cr-rich garnets in of SCLM base show an increase in Ca. Joined ilmenites and Cr diopside heated to 40 mw/m^2 trends (Fe#~15-17;

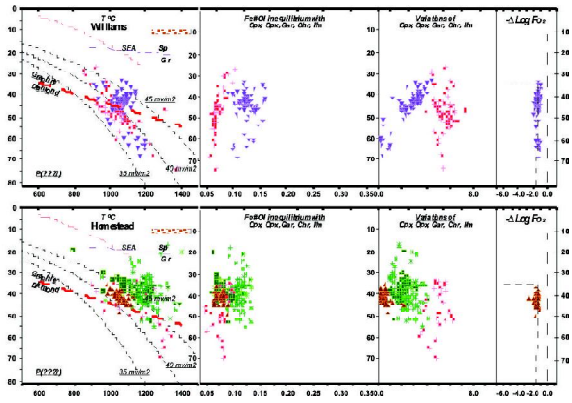

Fig.7. PTXFO$_2$ diagrams for the minerals from concentrates Eocene Williams (Hearn, McGee, 1984) and Homestead (Hearn, 2004) kimberlite pipes (Montana) Symbols see Fig 5.

11-14; 9-10) result from refertilization. PT conditions also tend to be divided to relatively low heated and those overheated at the shallow level. Chromite PT estimates show split trends (Fe#~10; 12) at 55-40kbar.

The HT conditions with sub-adiabatic path are detected for some ilmenites in the middle and upper parts of the lithospheric mantle section.

Xenocrysts from Chicken Park Vendian kimberlites (Lester & Larson, 1996; Coopersmiths et al , 2003; Hausel, 1998) allow to reconstruct SCLM divided at 40 kbar by a heated horizon where the garnet PT trend reveals an inflection with high rise in Fe# to the top. The base of SCLM is heated to 1500°C (PT for Opx).

The SCLM beneath Iron Mountain is divided at 40 kbar. In the upper part Fe# in garnets increases towards the top. In lower part increase in CaO and Fe-rich Cpx refer to refertilizations as well as polybaric branch of AFC differentiated ilmenites, Cpx show Fe#s intermediate between those for garnets and ilmenites.

GEOCHEMISTRY

Sloan peridotitic garnets show rounded REE patterns with humps to Nd to Gd and small U, Ba Nb,Ta peaks, varying Zr indicating mixed subduction and metasomatic features. The Cpx patterns increase the inclinations to low mantle part 50<Gd/Yb <80. The small troughs of Zr are typical for all of them. Enrichment in Ba is a result of the presence of fluid inclusions. The trace elements for ilmenites are very uniform with the strong peaks in Ta-Nb, weaker ones in Hf-Zr and evident for Pb. But some ilmenites have higher Rb and Ba, probably due to metasomatism. One ulvospinel shows inclined REE patterns and moderate enrichment in HFSE. Eclogitic Cpx show peaks in Ba. U, Sr, Pb.

Garnet form KL-I with increasing Cr reveals lower REE and progressive S-shaping, with pressure increase. Cpx REE show rotation about Gd due to modal garnet variations in their source. Zr-Hf depletion is rare but Ta-Nb are common, increasing with U peaks which is common for subduction processes.

Deep-seated Cpx LREE –Th enrichment reflects carbonatite signs, Cpx from Sp lherzolites displays LREE U, Ba rise relating to ancient subduction. Ilmenites reveal inclined REE patterns with varying HREE and showing lower U, Ta-Nb and Zr-Hf peaks common for metasomatites.

DISCUSSION

The Sloan and KL-1 pipes reveal different processes of extensive reaction of the mantle

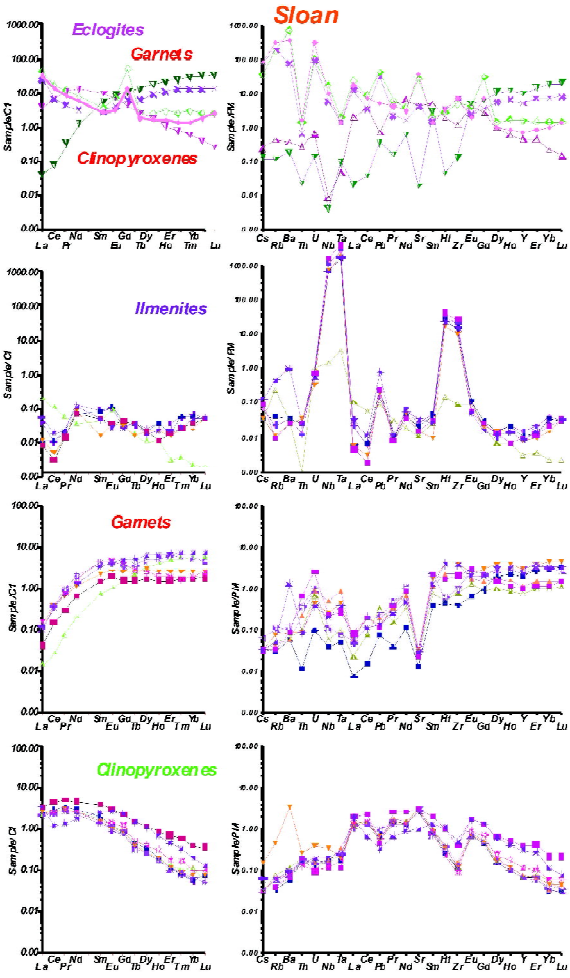

Fig. 8. Trace element patterns for minerals from deep-seated inclusions from Sloan pipe

protolith with ancient melts and protokimberlites. The Sloan SCLM was subjected from base to top with protokimberlites reactions revealed by the uniform Cpx trace elements from all parts of the mantle section and continuous trends of chromites. The KL–1 SCLM is diverse in composition containing abundant subduction matter (high Mn, Ba and Sr) was metasomatized and homogenized by subduction-related melts, plumes and their alkaline derivatives (O'Brien et al., 1995) and then by protokimberlites. The high heterogeneity of the mantle beneath the Wyoming craton was probably an original feature of the Wyoming craton keel composed of high angle slabs merged in craton margins. Position and compositions of the eclogites in the mantle section of different pipes is uncertain. The Re/Os ages for the peridotitic minerals indicate Archean to Proterozoic events and later refertillizations (Carlson & Irving, 1994; Rudnick et al., 1999).

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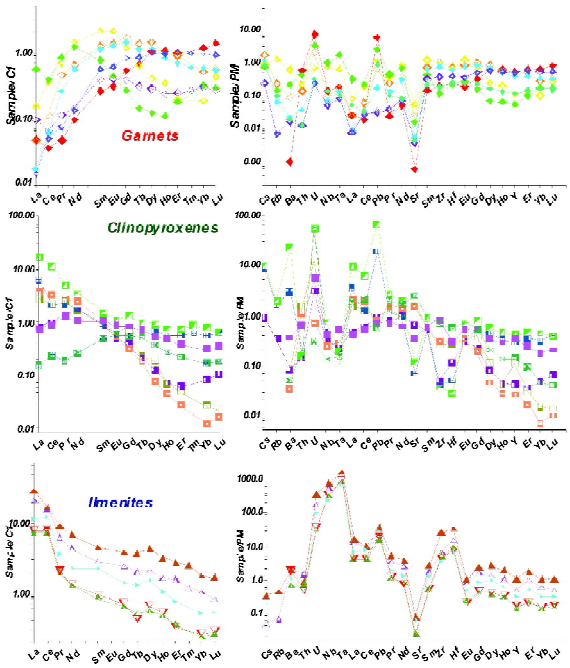

Fig. 9. Trace element patterns for minerals from deep-seated inclusions from Kelsey Lake-1 pipe.

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