EMPIRICAL CHROMITE AND ILMENITE THERMOBEROMETRY FOR MANTLE PERIDOTITES OF SPINEL FACIES

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Chromite monomineral thermo and barometry. Dependence of the Cr/ (Cr+Al) in spinel [16, 21] from the pressure determined using Al-En barometry was calibrated using 300 associations (R=0.84). ***P=0.86347*(Cr/ (Cr+Al)* T°C/14+Ti*0.1)*** for the pressures grater then 32kbar P=P-10. The second approximation ***P= P=0.0004*P³-0.0274*P²+1.4343*P*** brings to the lineal correlations between the pressures determined using ***Chr*** and ***OPx***. The temperatures are determined using monomineral version of the Ol-Sp thermometer [15]:

$$T^oC= (6530. +28.*P+ (5000. +10.8*P)*(1-2*Fe_{Ol})-1960.*(1. +Ti_{Sp})*(Mg_{Sp}-Fe_{Sp}) +18620. *Cr\#_{Sp}+25150.*(Fe^{3+}_{Sp}+Ti_{Sp}/2.))/ (8.31441*Ln (Fe_{Sp}*Mg_{Ol}/Mg_{Sp}/Fe_{Ol})+4.705)$$ {1}.

The ***Fo*** (forsterite) is calculated with empirical equations estimated on the behavior of the Fo content in mantle sections based on 2200 peridotite associations of the xenoiths from kimerlites The separate formulas are suggested for the P >30 kbar ***Fo***=0.06+0.0005*P and ***P=0.095+0.0001*P*** for the lower pressures where the mantle rocks are usually more ferriferous due to the interaction of the basaltic melts located in the astenosphere.

This modification n of the thermometer give the lineal correlation with the estimates made with bi – mineral Ol-Sp method (R2=0.98). The highest deviations are found for the most Hi – and Low –T°C part of the diagram (Fig. 1).

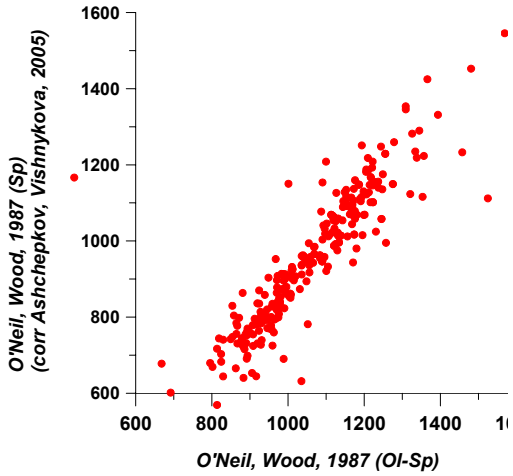

Fig. 1. Correlation diagram for the temperatures determined with the bi- mineral and monomineral chromite thermometer

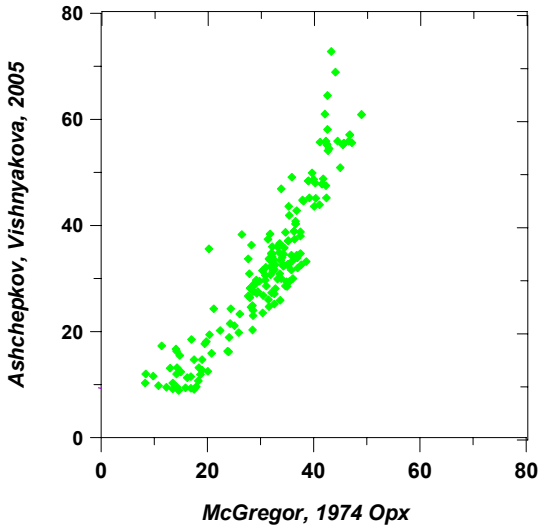

Fig. 2. Correlation diagram for the pressures determined with the Opx Al barometer of McGregor and monomineral chromite barometer

The estimates of the Ol –Sp [15, 20] thermometers give the better correlations with the two – pyroxene and Opx methods (r=0.78), the others Ol-Sp methods sometimes produce even negative correlations.

The main problem of the Cr- spinel thermometry is not good coincidence of the temperatures produced by Ol-Sp (Opx) [9, 10] barometry with those obtained with the two-pyroxene and other thermometric methods for mantle peridotites. This may be explained by several reasons:

1) difference of the system of the calibration from the natural associations;

2) disequilibrium of the Cr- spinel- Ga exchange of Fe-Mg and Cr-Al) from the Ca-Mg exchange working for the pyroxenes what may be most realistic because they may proceed with different rates and even related with the different processes.

As the barometers the dependence of the Cr-in Sp from the pressure in the garnet peridotites [8, 15, 21] was used. The Cr content in the liquids in equilibrium with the garnet peridotites is dependent on the T°C. The correction on this parameter was made $P_0 = 0.86347*\ Cr/\ (Cr+Al)*(T^oC)/14 +Ti*0.1(f.e.)$. The additional regression $P=-0.0053*P_0^2+1.1292*P_0+5.8059$ gives the better correlation (R_2=0.96) between the estimates on the Opx [9-10] and Cr- Sp barometer.

Checking of the agreement between the TP diagrams based on traditional polymineral versions of the mantle thermobarometry and Cr- method was made using analyses of the kimbelite peridotite xenoliths associations (~7000) published and dissertations of Ovchinnikov Yu.I., Malygina E.V., Kuligin S.S. and new data (>15000 analyses) from the reports for ALROSA company.

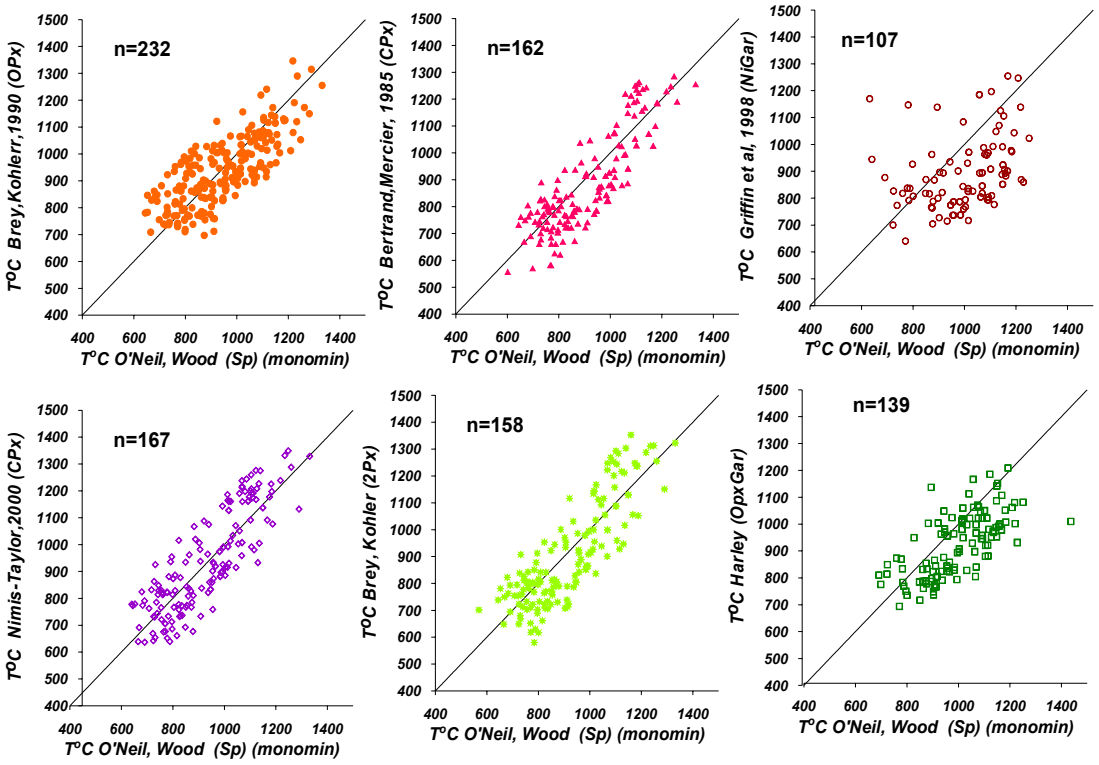

Fig 3. Correlation diagrams for the pressure values determined with Cr-Sp barometer and some other barometers used for the mantle peridotite associations.

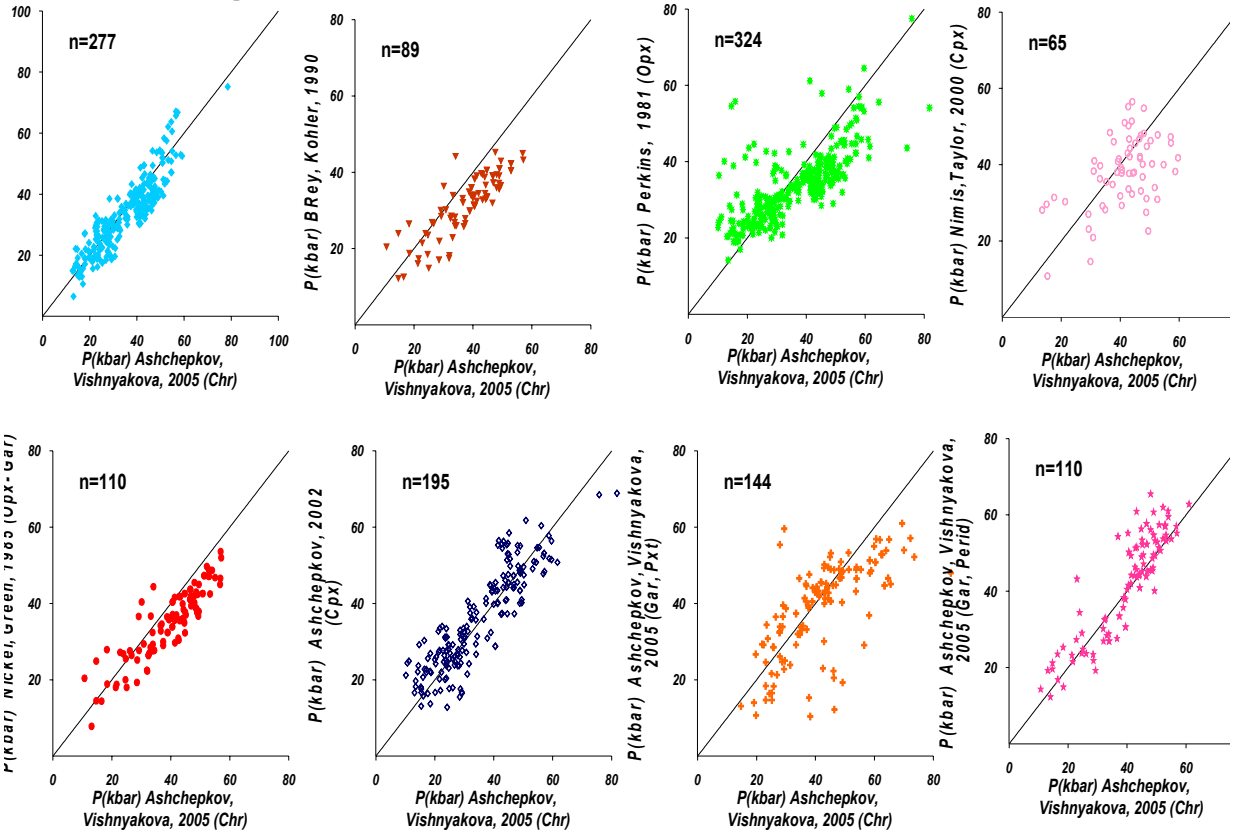

Fig.4. Correlation diagrams for the pressure values determined with Cr-Sp barometer and some other barometers used for the mantle peridotite associations

In most cases the coincidence of the Sp –estimates and the other common mantle thermobarometric methods are very high. The oxygen fugacity fO2 calculated with ***Sp-Ol*** oxybarometer [20] give the lineal correlation with monomineral version made in the same manner (R-0.96). $\Delta FO_2^{sp-ol} = 1.016 * \Delta FO_2^{sp} - 0.5016$.

Ilmenite monomineral thermo and barometry

The dependence of the geikilite minal from the pressure was calibrated using correlation of the peridotite layering and the levels of the magmatic sources crystallizing ilmenite megacrysts for the 30 kimberlite pipes of the Siberian platform, Africa and North and South America.

The pressure is determined as the correlation of the geikelite content in pycroilmentes from the determined pressure by common peridotite barometric methods, which in turn, is in a good agreement with the TiO_2 content.

P = P = (TiO2-23.)*2.15-(T°C-700)/20*MgO*Cr2O3-1.5*MnO)*T°C/1273

and further P=***10*(60-P)/60+P***.

For the ilmenite the temperatures are calculating using the monomineral version of the Ol-Il thermometer: ***T°C=(-13715.+DVT.*P*1000+3785*(2*Fe#ol-1)+2830*(gk-ilm)-19560*hem***

-7840*esk+45122*hem*esk)/(2.231-8.3143*ln(KD$_o$) +200 {5.4.1}

где ***esk=Cr/2 (ф.е.)***

hem=1-xesk-Ti+Mn

gk=Mg

ilm=1-esk-hem-gk

DVT=0.011*(gk-ilm)-0.047+0.015*(2*Fe#^{ol}-1)

KD$_{oi}$ = (1-Fe#^{ol})*ilm/(Fe#^{ol} *gk).

The forsterite content for (**1- *Fo)*** or ***Fe#^{ol}***) for the pressures <30 kbar are determined as ***(1-Fo) =0.11+0.00025*P,*** and higher ***Fo^{ol} =0.10+0.00025*P.***

The estimates of the Ilmenite thermobarometry give the position of the metasomatites and some pyroxenites and MARIDs and he mantle sequences, as well as the megacrystalline Ilm n- rocks and allow reconstructing the TP for the vein systems and feeding channels and associated interacted rocks. In most cases determination of the TP parameters fo the ilmenites reveal the polybaric fractionation of the protokimberlite melts and several stages of the melt percolations within the mantle columns beneath the kimberlite pipes.

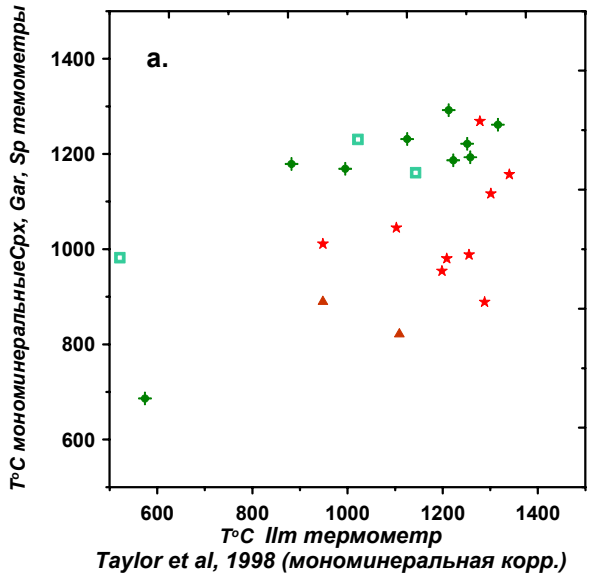

Fig 5. Correlation diagrams for the temperature values determined with Ilm thermometer and some other methods used for the mantle peridotite associations

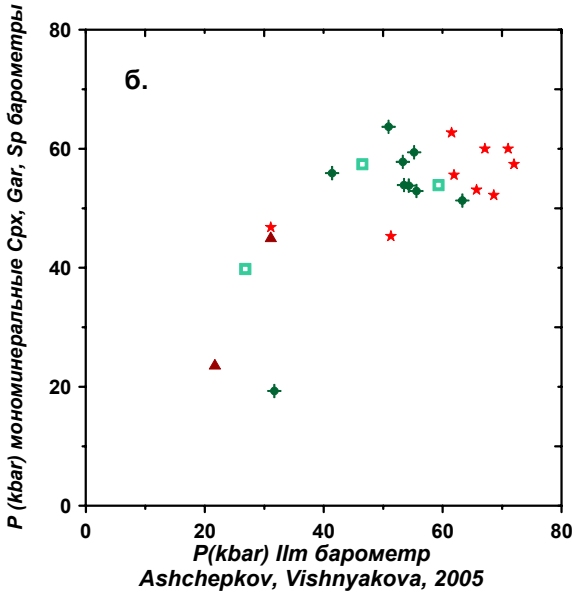

Fig.6. Correlation diagrams for the pressure values determined with Ilm barometer and some other barometers used for the mantle peridotite associations

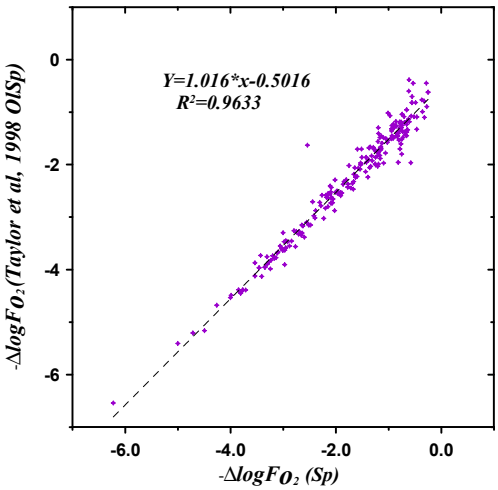

Fig. 7. The correlation of the Δ FO_2, determined with the Monomineral and bi – mineral versions of the (Ol-Sp) oxybarometer

Application of the TP- fO_2 **estimates for the different kimberlite fields of the Siberian platform**

The TP estimates using the chromite thermobarometer give very close geoterm positions and mantle layering of the mantle columns beneath as those determined by pyroxenes. As a rule, they mark the irregularly heated harzburgite and dunite horizons in lower parts that are not determined by the pyroxenes and garnets. For diamond inclusions they define high ToC to 1500°C at the basement of the mantle columns. Hi-T is found also at 40 kbar for pyroxenite lens and in the garnet- spinel facie, owing close conditions to Cpx.

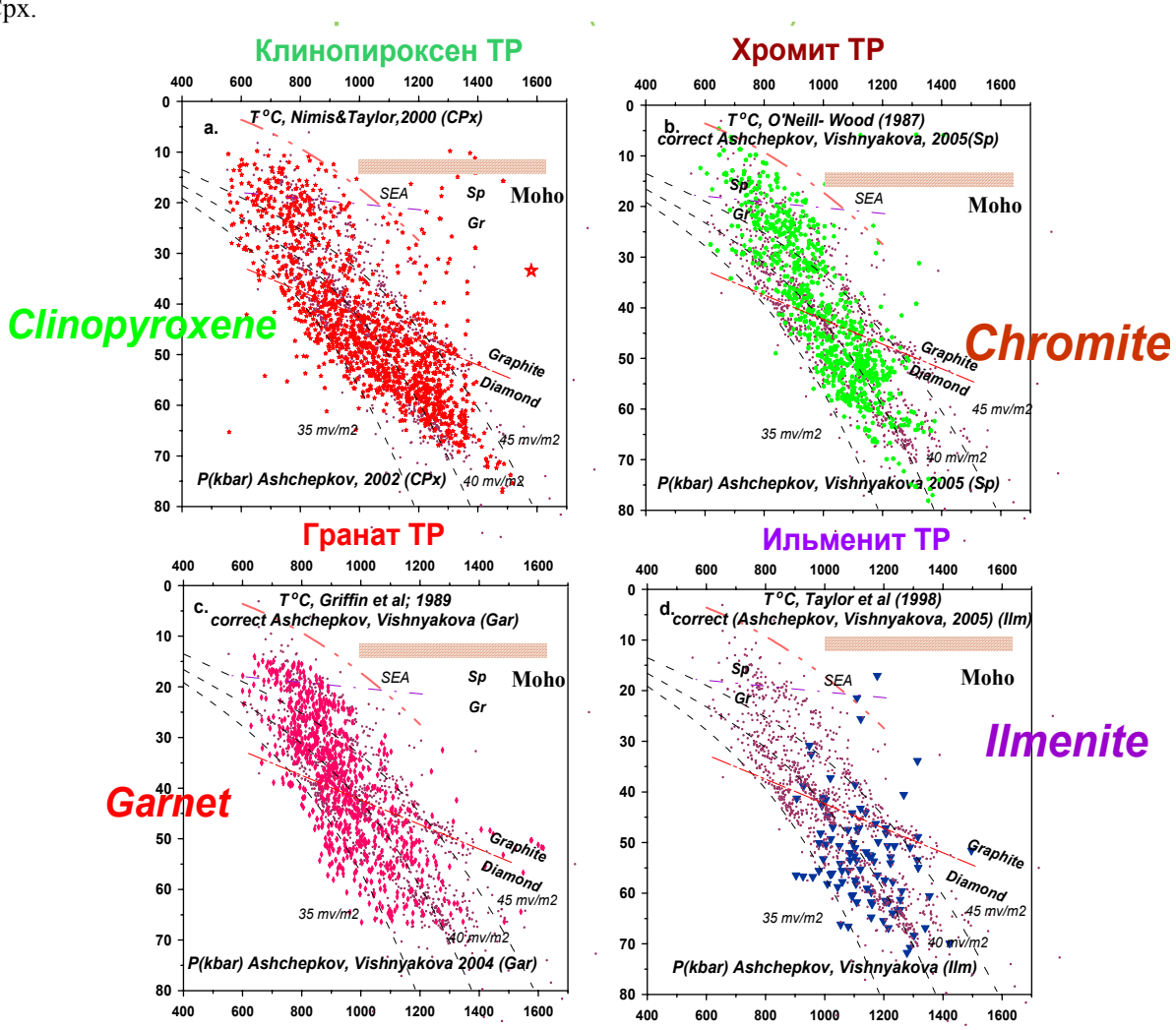

Fig. 8. The TP plots for the xenoliths from whole world kimberlites (2400 associations) produced with the a) Cpx , Cr-Spinel, Garnet, and Pycroilmenite monomineral thermobarometers plotted together with the values determined by the Opx thermobarometer.

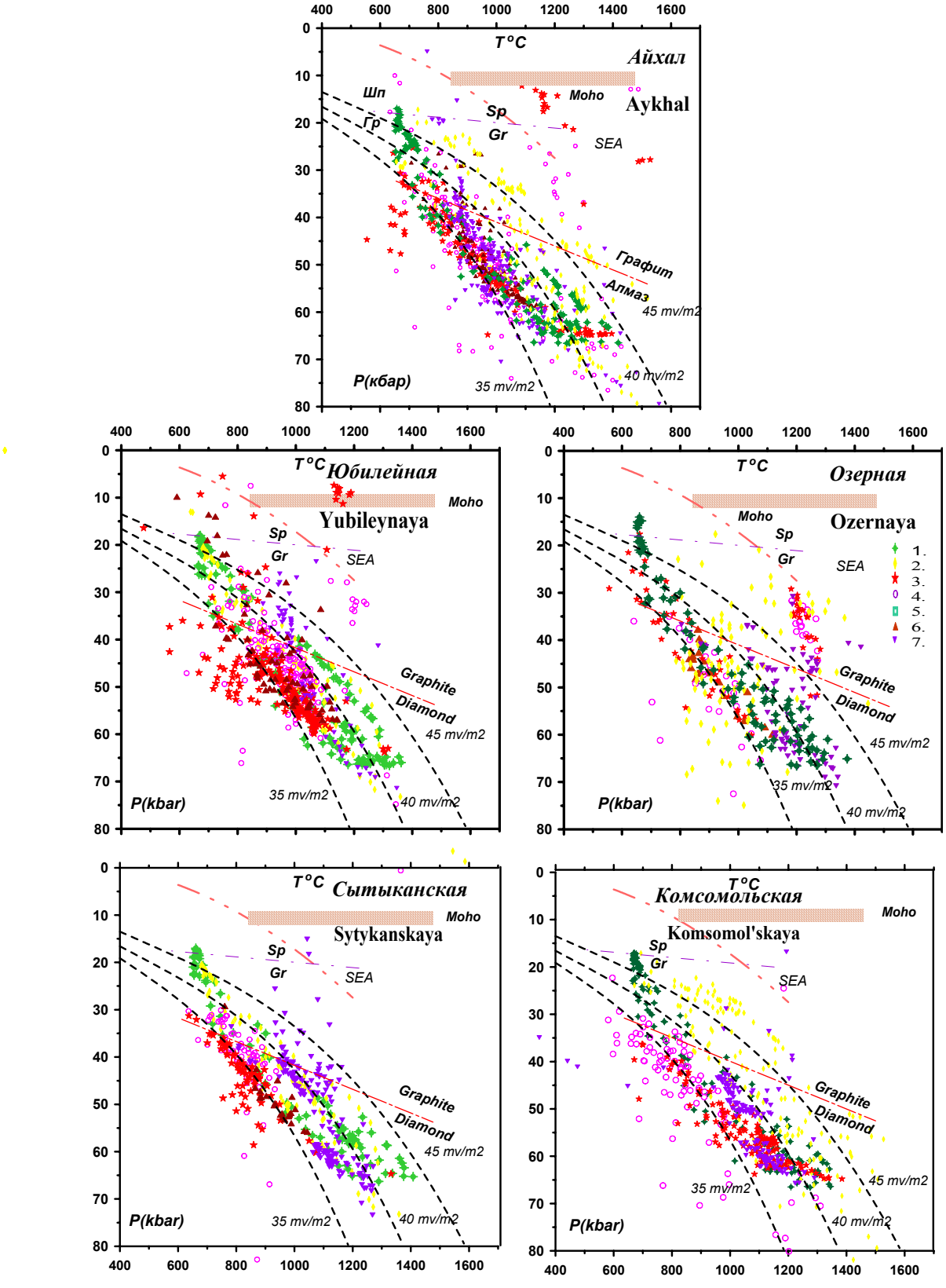

Рис. 9. TP estimates for the kimberlite pipes of the Alakite region Russia. 1. garnet thermobarometry, for the common peridotites [7](Ashchepkov, Vishnyakova, 2004); 2- the same for pyroxenites; 3.- Cpx thermobarometry [1,5]; 4- Cpx Cr-thermobarometry [4] (Nimis, Taylor, 2002); 5. Opx thermobarometry [9]-[10] (Brey , Kohler, 1990- McGregor, 1974); 6. Cr- Sp [4](this paper); 7. Ilmenite [4](this paper).

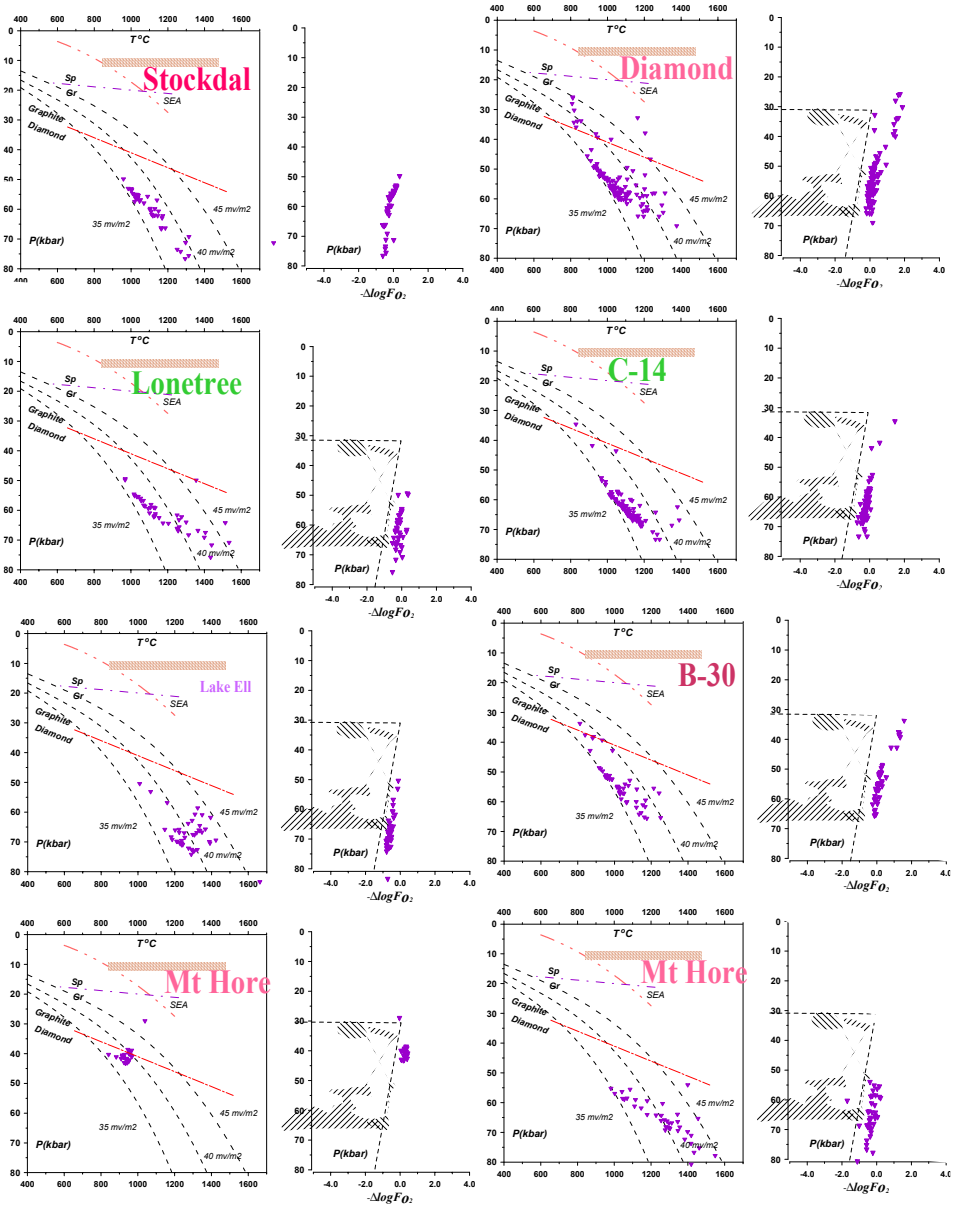

Fig. 10.

The TP conditions with Ilm and Cr-Sp thermobarometry and other methods were used for concentrates from the kimberlites in Yakutia (>50) and other World regions (~40 pipes) showing the good agreement with the other polymineral methods of he mantle thermobarometry [9-15;17,19,20]

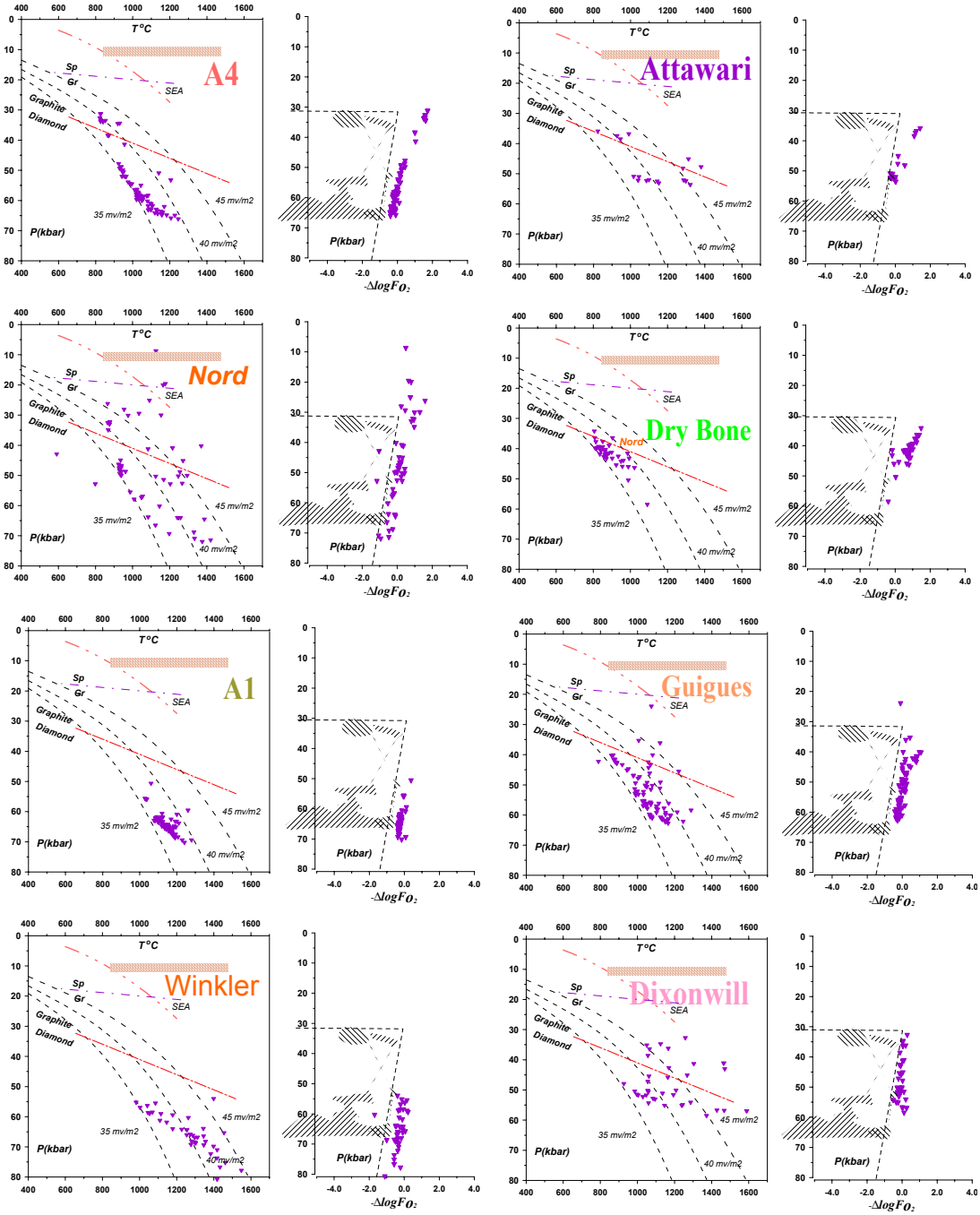

Рис. 11. TP estimates made with the Monomineral version of the Ilmenite thermobarometry (this paper) for the concentrate from the North America kimberlite pipes (Montana) (data of D. Schulze et al, 1995 [18])

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