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Volcanic Pipe of the Namuaiv Mountain

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Abstract. This research was aimed at reconstructing thermodynamic conditions required for the studied mineral assemblages to be created and exist in nature. The results of the investigations confirm to the recent ideas about an important, even leading, role of temperature, pressure and dioxide carbon in diamond formation in volcanic pipes. The results of this theoretical research allows assuming that one of the reasons for the absence of diamonds in the Namuaiv Mountain volcanic pipe may lie in the increased content of water and oxidizing environmental conditions of their formation.

Keywords: carbon; diamond; volcanic pipes; fluid; temperature; pressure; modeling; multisystem.

The previous research of the diamond formational conditions in the Khibiny carbonate-silicate rocks established a possibility for diamonds and carbon to form in the carbonate alkaline polycomponent systems under the conditions of a non-equilibrium environment [1]. This process may be facilitated by carbon existing in nature, reducing conditions of the environment under certain pressure and temperature.

In the northeastern sector of the Khibiny intrusion (Namuaiv Mt.), three volcanic pipes occur. One of the pipes was drilled down to a depth of 500 m (bh. 1635), and studied in detail [2]. The results of this research are demonstrated in Figure 1 as depth-related rhythmically oscillating oxide distribution.

For the sake of comparison, a broken line in the figure shows the content of these oxides in the Khibiny carbonatite stock from the depth of 439 m [3]. It is obvious from the figure that low content of SiO₂, Al₂O₃, K₂O, CO₂ and higher amount of CaO, MgO is traced along the whole length of the volcanic pipe.

The intrusions formed under the relevant fluid regime, active contribution of fluids, which physical and chemical properties are often affect the compositions of mineral assemblages. This research was aimed at reconstructing temperature and pressure conditions required for the studied mineral assemblages to be created and exist in nature. To model physical and chemical criteria of a natural process, a geochemical model of the system is created on the basis of a macro- and microelement distribution mode for the studied target. Therefore, the knowledge of the chemical and mineralogical composition of the studied rock is essential to investigate the behavior of its solid and fluid phase as a function of the environment's pressure and temperature.

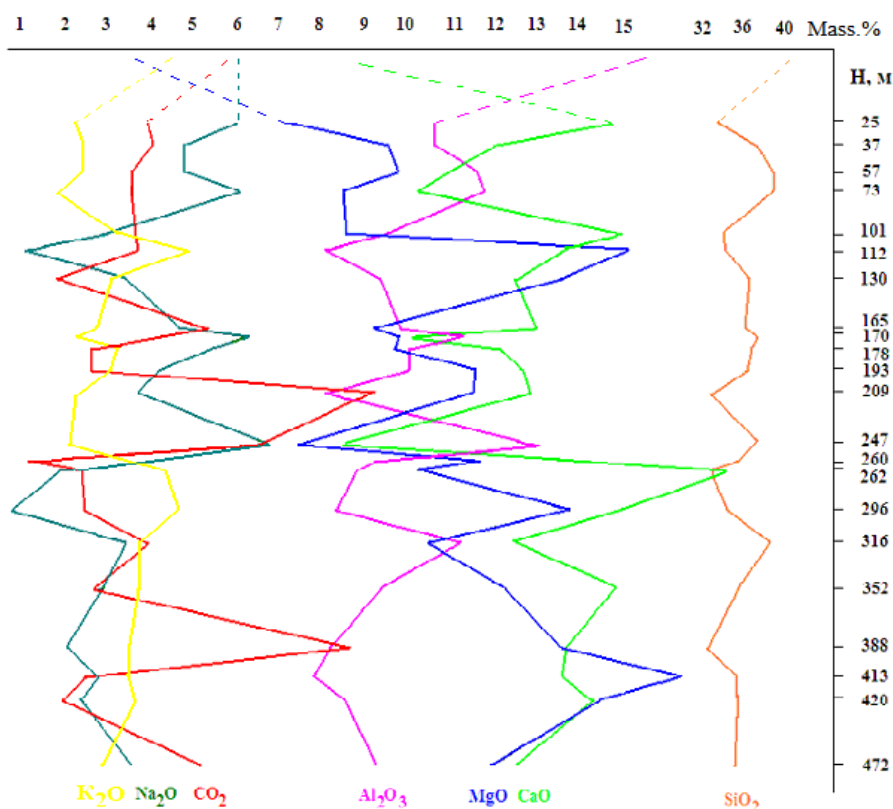


Fig. 1. Basic oxide distribution in samples from bh. 1635

The results of physical and chemical modeling as a research technique allow establishing diverse factors affecting the process of formation and evolution of minerals, mineral assemblages, and fluid in nature. The results of the chemical analysis of natural samples with maximum ($H = 209$ m) and minimum ($H = 260$ m) carbon dioxide content were used as initial data for the modeling (Table 1).

Table 1

Maximum and minimum CO_2 content in the volcanic pipe as initial data to calculate multisystems

Oxides	Content	
	CO_2 (max)	CO_2 (min)
SiO_2	33.16	35.79
TiO_2	2.72	2.98
Al_2O_3	8.01	9.37
Fe_2O_3	6.12	5.15
FeO	4.41	5.50
MgO	11.84	11.67
CaO	12.76	14.66
Na_2O	3.72	3.79
K_2O	2.20	3.85
P_2O_5	0.44	1.09
CO_2	9.25	1.22
S	0.12	0.22
F	0.50	0.26
H_2O	4.05	3.55
Σ	99.3	99.1

The geochemical process modeling serves not as a simple way of visual and reliable imaging of actual data, but also a tool to obtain fresh data on the processes which ultimate results are seen in the field. The physical and chemical modeling of the complex fluid composition behavior in equilibrium with solid phase is, therefore, made through thermal dynamic calculations for the created multisystems for each sample (Selector). The results of the chemical rock analysis serve as source data for the modeling-related investigations in order to identify the composition of solid and fluid phases under different P-T parameters. In this research, each multisystem contained 14 independent components (elements), i.e. Al-Ca-F-Fe-K-Mg-Na-P-S-Si-Ti-C-H-O. The calculation matrix of the multisystem was composed from 42 dependent components of mineral phases and a fluid phase that included ten gaseous components, i.e. H₂O, H₂, O₂, CO, CO₂, H₂S, SO₂, S₂, CH₄, C₂H₆. The identification of mechanisms for distributing fluid components may provide quite valuable information to solve essential problems of ore-formation related petrogenesis. The mineral phases in the multisystems are based on the results of studying the composition of volcanic pipe samples (silicates, aluminosilicates, oxides, carbonates, apatites, sulphides, halides) [2].

The physical and chemical modeling of multisystems that allows evaluating the composition of the fluid phase in equilibrium with mineral phases stipulates re-calculation of the chemical analysis results into molar element content in 1 kg of the studied rock (Table 2). These data served an initial vector for numerical implementation of the studied models using a Gibbs free energy minimization technique, which universality is applicable to the decision of specific physical and chemical tasks of geochemistry [4].

Table 2

Content of independent multisystem components (Vector b)

Elements	Khibiny stock	Volcanic pipe (CO ₂ max)	Volcanic pipe (CO ₂ min)	- 4 wt.% H ₂ O	- 4 wt.% H ₂ O and + 0.2 mol/kg C	- 4 wt.% H ₂ O and + 0.3 mol/kg C
	Vectors					
	b ₀	b ₁	b ₂	b ₃	b ₄	b ₅
	Mol/kg					
Si	6.69143	5.557817	6.010727	5.73319	5.73319	5.73319
Ti	0.13969	0.342972	0.376515	0.353794	0.353794	0.353794
Al	3.01849	1.582260	1.854644	1.632187	1.632187	1.632187
Fe	1.34105	1.390051	1.423361	1.433913	1.433913	1.433913
Mg	0.91524	2.958353	2.921761	3.051702	3.051702	3.051702
Ca	1.60061	2.291467	2.637968	2.363772	2.363772	2.363772
Na	1.94608	1.208871	1.234104	1.247022	1.247022	1.247022
K	0.93902	0.470404	0.864563	0.485247	0.485247	0.485247
P	0.1133	0.062433	0.154976	0.064403	0.064403	0.064403
C	1.3315	2.116621	0.279729	2.18341	2.38341	2.48341
S	0.39068	0.037687	0.069232	0.038876	0.038876	0.038876
F	0.52904	0.265035	0.138096	0.273462	0.273462	0.273462
H	0.11157	4.527872	3.976886	1.167686	1.167686	1.167686
O	27.43901	28.693685	26.849645	27.847567	27.847567	27.847567

This table represents Vector b_0 of the Khibiny carbonatite multisystem for the sake of comparison.

The physical and chemical multisystem modeling was made under the following thermodynamic parameters: up to 900°C, and 1 000, 5 000 and 10 000 bar (P-T parameters under which a possibility of common diamond and carbon formation in the carbonatite stock is found). The results of calculation for major initial vectors b_1 and b_2 (phase and mineral compositions, partial pressure of the fluid components and activity factors) are demonstrated in Tables 3 and 4.

The calculation of the multisystem with high content of carbon dioxide (Table 2) has established the presence of anorthite, enstatite, titanite, and abundant calcium carbonate. The low temperature area is occupied by soda along with ilmenite, fluorite, pyrite which are transformed into rutile and villiaumite under the influence of increasing temperature. Nepheline appears in the area of high temperature and applied pressure. Fluorapatite is stable almost along the whole P-T interval. Somewhat fluorite concentration is found in the system under the low temperature. These thermodynamic parameters result in water and minor carbon dioxide as major fluid components. However, when the temperature exceeds 700° C, sulphur dioxide commensurate in concentration with carbon dioxide is registered in the fluid. The fluid regime is reducing while with increasing temperature it becomes oxidizing.

In accordance with the results of calculating a multisystem with minimum carbon dioxide content (Vector b_2 , Table 3), it is evident that lime, magnetite, biotite, nepheline, microcline, rutile, and pyrrhotite is found along the whole P-T range. The minimum carbon dioxide concentration favours hydroxylapatite which is stable almost along with the whole P-T range to be formed in the system. Fluorapatite is observed only under the temperature of 1100° C together with fluorite. The fluid has water – carbon dioxide composition with insignificant hydrogen sulfide. With increasing temperature the fluid regime in this system becomes oxidizing.

The resultant calculation data with the usage of the initial information allow concluding as follows: a possibility of diamond formation in the volcanic pipe of the Namuaiv Mountain under the specified thermodynamic parameters both at maximum and minimum concentrations of carbon dioxide in a natural sample is completely excluded.

The comparison of the calculation results and implemented analysis with the data of chemical composition for the Khibiny carbonatite stock and volcanic pipe of the Namuaiv Mountain allows establishing a few interesting differences. This resulted in further calculations of the Vector b_1 multisystem executed with the three-time increased sodium^{**} and carbon content (from 3.63 to 6.33 mol/kg). The theoretical calculations of the renewed composition were made under $T = 300, 500$ and 700°C , and $P = 1000, 5000$ and 10000 bar. The results of the calculation are shown in Table 5. It is obvious from these data that the variation of the initial composition in the multisystems caused redistribution of concentrations of almost all dependent components, and prevented diamond generation. It should be noted that earlier absent graphite, nepheline, wollastonite, and epidote appeared in the system along with reducing concentrations of calcite and muscovite. Magnetite and partially biotite disappeared. More significant variations took place in the composition of the fluid phase which contained more hydrocarbons (methane-ethane) with minor content of water and hydrogen.

Numerous investigations of the actual data allowed certain authors [5-7, 9] to suppose possible dry (water-free) process of carbon and diamond formation under the conditions of relatively low pressure and temperature. To verify this assumption, the chemical composition of the Vector b_1 multisystem was adjusted by four-time reducing the

* Sodium can function as a catalyst in accordance with [8].

water content and increasing carbon content (Table 1). The results of this investigation stage are shown in Table 6. The initial increase of the carbon content in the multisystem favored slight increase of calcium carbonate concentration. The latter resulted in parallel formation of carbon and diamond.

The calculations demonstrate that the abundance of generated carbon is twice as much as that of diamonds (see also [1]). The variations in the multisystem resulted in the reducing fluid regime with the composition significantly dominated by hydrocarbons, hydrogen, and minor CO, SO₂, S₂. The calculations imply that new compositional conditions led to the formation of pyrrhotite and ilmenite.

Thus, this theoretical research allows assuming that one of the reasons for the absence of diamonds in the Namuaiv Mountain volcanic pipe may lie in the increased content of water and oxidizing environmental conditions of their formation.

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Table 3

**Calculation of the solid phase component composition
(CO₂ content – max, H = 209 m of the volcanic pipe)**

Composition	500	700	900	500	700	900	500	700	900
	P = 1000 bar			P = 5000 bar			P = 10000 bar		
CaCO ₃	15.03	15.04	21.38	15.18	15.04	21.38	15.25	15.04	21.38
Hematite	3.92	сл.	-	4.03	сл.	-	4.03	сл.	-
Magnetite	7.31	11.25	11.25	7.17	11.25	11.25	7.17	11.25	11.25
Albite	0.03	сл.	сл.	0.19	сл.	сл.	0.27	сл.	сл.
Anorthite	16.2	16.22	2.15	16.07	16.22	2.15	16.02	16.28	2.15
Enstatite	31.08	31.14	31.14	31.05	31.14	31.14	31.04	31.14	31.14
Nepheline	-	-	14.37	-	-	14.37	-	-	14.37
Microcline	13.70	13.73	13.73	13.69	13.73	13.73	13.69	13.73	13.73
Rutile	-	2.23	2.23	2.24	2.23	2.23	2.39	2.23	2.23
Ilmenite	2.24	сл.	сл.	-	-	сл.	-	-	сл.
Titanite	1.53	1.57	1.57	1.28	1.57	1.57	1.16	1.57	1.57
Pyrite	0.20	-	-	0.23	-	-	0.23	0.02	-
Fluorapatite	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Villiaumite	-	-	1.08	-	-	1.08	-	-	1.08
Fluorite	1.0	1.0	-	1.0	1.0	-	1.0	1.0	-
Soda Na ₂ CO ₃	6.70	6.72	-	6.66	6.72	-	6.64	6.72	-

Composition of the fluid phase

Composition	500	700	900	500	700	900	500	700	900
	P = 1000 bar			P = 5000 bar			P = 10000 bar		
H ₂	2.1e-02	1.3e-01	6.9e-01	3.3e-02	1.5e-01	1.1e-00	4.3e-02	1.1e-01	1.0e-00
	2.8e-02	1.6e-01	8.1e-01	1.1e-01	4.0e-01	2.3e-00	4.2e-01	6.2e-01	4.5e-00
H ₂ O	9.6e+02	9.5e+02	9.5e+02	4.9e+03	4.8e+03	4.8e+03	9.7e+03	9.5e+03	9.5e+03
	4.4e+02	7.2e+02	8.7e+02	2.0e+03	3.6e+03	4.8e+03	8.8e+03	1.3e+04	1.6e+04
H ₂ S	2.0e-00	2.8e-00	2.6e+00	2.4e-00	1.4e+01	1.4e+01	1.5e-00	1.4e+01	2.8e+01
	2.0e-00	3.1e-00	3.0e+00	1.2e+01	5.7e+01	4.9e+01	6.9e+01	3.5e+02	4.5e+02
O ₂	3.8e-20	2.3e-14	4.1e-11	1.2e-20	2.9e-14	6.1e-11	3.0e-21	4.2e-14	6.2e-11
	5.0e-20	2.9e-14	5.1e-11	6.2e-20	1.19e-13	1.9e-10	8.2e-20	6.1e-13	5.8e-10

Table 4

Calculation of the solid phase component composition
(CO₂ content – min, H = 260 m of the volcanic pipe)

Composition	500	700	900	500	700	900	500	700	900
	P = 1000 bar			P = 5000 bar			P = 10000 bar		
CaO (lime)	13.74	13.75	13.93	13.74	13.75	13.93	13.72	13.72	13.92
Magnetite	10.55	11.00	10.14	10.24	10.88	9.82	10.23	10.73	9.64
Enstatite	29.78	29.80	23.21	29.77	29.79	23.21	29.77	29.78	23.20
Annite	1.01	0.04	0.57	1.76	0.01	0.98	1.78	0.41	1.24
Phlogopite	0.59	0.59	10.26	0.59	0.59	10.26	0.59	0.59	10.26
Mica (musc.)	9.03	9.31	-	9.30	9.31	-	9.30	9.30	-
Aegirine (acm)	-	-	2.55	-	-	2.56	-	-	2.55
Nepheline	7.85	7.86	14.68	7.85	7.85	14.68	7.85	7.85	14.68
Microcline	17.34	17.88	17.96	16.92	17.84	17.83	16.91	17.67	17.60
Rutile	3.10	3.10	3.14	3.10	3.10	3.10	3.09	3.10	3.14
Pyrite	0.22	-	-	0.42	0.06	с.л.	0.43	0.17	-
Pyrrhotite	0.15	0.34	0.28	с.л.	0.41	0.40	-	0.33	0.47
Apatite OH	2.67	2.67	2.71	2.67	2.67	2.71	2.67	2.67	2.71
Villiaumite	0.60	0.60	0.61	0.60	0.60	0.61	0.60	0.60	0.61
Soda Na ₂ CO ₃	3.05	3.05	-	3.05	3.05	-	3.05	3.05	-

Composition of the fluid phase

Composition	500	700	900	500	700	900	500	70	900
	Gas: partial pressure – P _i / fugacity - f _i								
H ₂	3.5e-1	6.4e-1	4.0e-0	1.5e-1	6.4e-1	3.7e-0	5.5e-2	9.1e-1	2.4e-0
	3.9e-1	7.9e-1	4.7e-0	5.0e-1	1.9e-0	8.1e-0	5.4e-1	5.6e-0	1.1e-1
H ₂ O	1.0e+3	9.8e+2	8.4e+2	5.0e+3	4.9e+3	4.2e+3	1.0e+4	1.0e+4	8.5e+3
	4.6e+3	7.5e+2	7.6e+2	2.1e+3	3.8e+3	4.3e+2	9.0e+3	1.4e+4	1.2e+3
O ₂	2.0e-22	9.4e-16	9.6e-13	6.7e-22	1.8e-15	4.0e-12	1.9e-21	5.8e-16	9.0e-12
	2.7e-22	1.2e-15	1.2e-12	3.6e-21	6.7e-15	1.3e-11	5.4e-21	8.4e-15	8.4e-11
CO ₂	-	-	1.4e+2	-	-	7.0e+2	-	-	1.4e+3
	-	-	1.7e+2	-	-	2.7e+3	-	-	2.4e+4
CO	-	-	1.0e-0	-	-	1.6e-0	-	-	1.5e-0
	-	-	1.4e-0	-	-	6.7e-0	-	-	2.3e+1
SO ₂	5.4e-3	6.8e-1	4.0e-1	2.5e-3	2.5e-0	5.4e-0	8.0e-3	4.2e-1	2.1e+1
	4.9e-4	7.3e-1	4.6e-1	1.9e-2	1.5e+1	2.7e+1	1.1e-0	2.7e+1	7.6e+2
H ₂ S	5.0e-0	1.8e+1	1.9e+1	4.1e-0	5.8e+1	6.0e+1	7.6e+1	7.4e+2	7.2e+1
	4.9e-01	2.0e+1	2.2e+1	1.9e+1	1.6e+2	2.1e+2	1.9e+1	1.6e+2	2.1e+2
CH ₄	-	-	9.8e-5	-	-	1.3e-4	-	-	6.5e-5
	-	-	1.3e-4	-	-	5.7e-4	-	-	1.3e-3
C ₂ H ₆	-	-	1.8e-12	-	-	3.5e-12	-	-	1.5e-12
	-	-	5.2e-12	-	-	2.9e-11	-	-	1.1e-10
S ₂	1.7e-5	2.1e-1	-	4.8e-5	1.1e-1	-	1.3e-4	6.4e-2	-
	2.5e-5	2.5e-2	-	1.9e-4	3.5e-1	-	2.5e-3	7.0e-1	-
ΣV _{total} , cm ³	358.8	411.4	501.4	335.0	341.6	372.9	329.5	332.9	357.7
V _{gas} , cm ³	58.4	110.9	188.8	34.76	41.31	60.61	29.6	32.7	45.8
Basic fluid	H ₂ O	H ₂ O>> H ₂ S	H ₂ O> CO ₂	H ₂ O>> H ₂ S	H ₂ O> H ₂ S	H ₂ O> CO ₂ > H ₂ S	H ₂ O	H ₂ O	H ₂ O> CO ₂

Table 5

Calculation of the solid phase component composition
(with varied sodium and carbon composition)

Composition	300	500	700	300	500	700	300	500	700
	P = 1000 bar			P = 5000 bar			P = 10000 bar		
	Content, wt. %								
Carbon	3.13	3.02	2.89	3.13	3.13	2.87	3.27	3.13	2.87
CaO (lime)	4.56	4.28	4.76	3.99	4.57	4.77	4.42	4.57	4.78
CaCO ₃	9.02	6.96	7.61	8.00	6.45	7.66	5.69	6.44	7.64
Wustite	6.63	8.82	8.82	8.81	6.63	8.83	7.69	6.63	8.33
Nepheline	7.25	-	-	4.39	-	-	-	-	-
Albite	sl.	sl.	-	sl.	sl.	-	sl.	sl.	-
Anorthite	-	7.11	11.39	sl.	7.11	11.39	sl.	7.11	11.39
Enstatite	28.75	28.18	28.81	28.75	28.75	28.82	28.74	28.76	28.82
Annite	5.17	-	-	-	5.17	-	-	5.17	-
Wollastonite	-	-	-	2.35	-	-	0.55	-	-
Epidote	-	-	-	-	-	-	7.46	-	-
Mica (musc.)	13.01	13.02	6.92	17.04	13.01	6.93	17.03	13.01	6.93
Microcline	-	2.82	7.09	-	sl.	7.09	-	sl.	7.09
Rutile	-	-	2.45	-	-	2.45	-	1.45	-
Titanite	6.00	6.01	-	6.00	6.01	-	6.00	sl.	6.00
Pirrhote	0.30	0.30	0.29	0.30	0.30	0.30	0.29	0.29	0.30
Fluor apatite	0.94	0.94	0.94	0.94	0.94	0.94	-	-	-
Whitlockite	-	-	-	-	-	-	0.86	0.87	0.87
Fluorite	0.85	0.85	0.85	0.85	0.85	0.85	0.92	0.92	0.92
Soda Na ₂ CO ₃	17.38	17.11	17.11	17.08	17.08	17.12	17.07	17.08	17.12

Composition of the fluid phase

Composition	300	500	700	300	500	700	300	500	700
	P = 1000 bar			P = 5000 bar			P = 10000 bar		
	Gas: partial pressure - P _i / fugacity - f _i								
H ₂	1.9e+1	7.7e+1	1.7e-0	3.4e+1	1.5e+2	2.7e-0	4.1e+1	1.9e+2	3.0e-0
	2.4e+1	9.5e+1	2.5e-0	1.1e+2	3.9e+2	1.5e+1	4.2e+2	1.2e+3	6.9e+1
H ₂ O	2.2e-0	1.6e+1	1.0e-4	1.8e+1	9.8e+1	3.5e-1	2.3e+1	2.5e+2	1.2e-3
	1.0e-0	1.2e+1	1.3e-2	7.7e-0	7.5e+1	1.4e-1	4.8e+1	3.5e+2	1.5e-0
H ₂ S	1.8e-3	7.5e-2	3.0e-6	4.0e-2	1.6e-1	7.0e-6	4.2e-3	1.8e-1	7.0e-6
	1.7e-3	8.3e-2	2.2e-6	1.9e-2	6.8e-1	4.0e-5	1.9e-1	4.7e-0	8.0e-4
O ₂	2.6e-31	1.8e-23	1.1e-44	1.7e-31	1.3e-23	6.3e-45	9.9e-32	8.4e-24	3.2e-45
	3.5e-31	2.3e-23	1.5e-44	8.7e-31	4.9e-23	5.2e-45	2.8e-30	1.2e-22	2.5e-43
SO ₂	3.9e-18	4.7e-13	9.1e-27	2.8e-18	3.4e-13	5.9e-27	1.4e-18	1.8e-13	2.4e-27
	3.6e-18	5.0e-13	5.3e-27	2.1e-17	2.0e-12	5.8e-26	1.9e-16	1.2e-11	1.2e-24
CO	6.6e-4	1.6e-1	5.1e-8	2.7e-4	7.9e-2	1.6e-8	9.5e-5	3.4e-2	4.1e-9
	9.7e-4	2.2e-1	8.3e-8	2.1e-3	4.2e-1	2.4e-7	5.7e-3	9.3e-1	9.2e-7
CO ₂	1.7e-4	3.8e-2	1.8e-8	1.2e-4	2.6e-2	1.1e-8	6.0e-5	1.5e-5	4.6e-9
	2.0e-4	4.6e-2	1.7e-8	7.1e-4	1.3e-1	9.3e-8	3.4e-3	4.3e-1	7.7e-7
CH ₄	9.8e+2	9.0e+2	9.9e+2	4.9e+3	4.7e+3	5.0e+3	9.9e+3	9.5e+3	9.9e+3
	1.4e+3	1.2e+3	1.5e+3	4.3e+4	2.7e+4	8.0e+4	7.8e+5	3.4e+5	3.1e+6
C ₂ H ₆	8.6e-1	1.7e-0	2.5e-1	1.2e+1	2.4e+1	3.8e-0	4.3e+1	8.3e+1	1.6e+3
	1.2e-0	1.4e-0	2.9e-1	2.4e+2	2.9e+2	1.5e+2	2.3e+4	1.5e+4	4.8e+4
S ₂	5.0e-16	2.6e-11	5.3e-24	8.8e-16	3.7e-11	1.1e-23	1.6e-15	5.9e-11	2.4e-23
	6.5e-16	3.1e-11	6.4e-24	3.5e-15	1.2e-10	6.2e-23	2.9e-14	6.4e-10	1.9e-21
ΣV _{total} , cm ³	379.1	410.9	370.4	331.0	343.4	333.8	320.3	329.6	312.4
V _{gas} , cm ³	85.6	114.3	63.6	36.9	47.0	33.8	29.3	36.3	26.5
Basic fluid	CH ₄	CH ₄	CH ₄	CH ₄	CH ₄	CH ₄	CH ₄	CH ₄	CH ₄
	>>H ₂ O	>>H ₂ O	>>H ₂ O	>>H ₂ O	>>H ₂ O	>>H ₂ O	>>H ₂ O	>>H ₂ O	>>H ₂ O

Table 6

Calculation of the solid phase component composition
(initial data in Table 2 of Vector b_1 for CO_2 max)

Composition	T = 500°C, P = 1000 bar			
	- 4 wt.% H ₂ O	- 4 wt.% H ₂ O + 0.2 wt.% C	- 4 wt.% H ₂ O + 0.3 wt.% C	- 4 wt.% H ₂ O + 0.5 wt.% C
Carbon	-	-	0.0053	0.1716
Diamond	-	-	0.0025	0.0791
CaCO ₃	15.22	16.00	15.99	15.96
Hematite	3.99	-	-	-
Magnetite	7.21	4.09	-	-
Albite	0.24	1.05	1.05	1.04
Anorthite	16.04	15.62	15.62	15.58
Enstatite	31.05	30.07	31.07	30.98
Annite	-	9.00	18.02	17.98
Microcline	13.69	8.80	3.89	3.88
Rutile	2.37	сл.	сл.	сл.
Ilmenite	-	5.44	5.44	5.44
Titanite	1.21	2.86	-	-
Pyrite	0.23	-	-	-
Pyrrhotite	-	0.33	0.33	0.34
Fluor apatite	1.097	1.098	1.097	1.095
Fluorite	0.997	0.998	0.997	0.995
Soda Na ₂ CO ₃	6.65	6.49	6.45	6.47

Composition of the fluid phase

Composition	T = 500°C, P = 1000 bar			
	- 4 wt.% H ₂ O	- 4 wt.% H ₂ O + 0.2 wt.% C	- 4 wt.% H ₂ O + 0.3 wt.% C	- 4 wt.% H ₂ O + 0.5 wt.% C
	Gas: partial pressure – P _i / figacity - f _i			
H ₂	1.9e-02	5.1e-01	1.7e-00	1.7e-00
	2.6e-02	6.7e-01	2.2e-00	2.2e-00
H ₂ O	9.0e+02	6.7e+02	4.3e+02	4.3e+02
	4.1e+02	3.7e+02	2.0e+02	2.0e+02
H ₂ S	1.9e-00	2.5e-00	1.4e-00	1.4e-00
	1.8e-00	2.4e-00	1.3e-00	1.4e-00
O ₂	3.8e-20	3.1e-23	1.2e-24	1.2e-24
	5.0e-20	4.1e-23	1.6e-24	1.6e-24
SO ₂	5.8e-01	2.4e-05	1.5e-07	1.5e-07
	5.2e-01	2.2e-05	1.4e-07	1.4e-07
CO	9.9e-04	1.2e-01	9.9e-01	9.9e-01
	1.4e-03	1.7e-01	1.5e-00	1.5e-00
CO ₂	9.8e+01	3.3e+02	5.6e+02	5.6e+02
	1.1e+02	3.9e+02	6.5e+02	6.5e+02
CH ₄	4.3e-09	1.2e-02	5.7e-00	5.7e-00
	6.0e-09	1.7e-02	8.1e-00	8.1e-00
C ₂ H ₆	1.6e-20	4.6e-09	3.2e-04	3.2e-04
	2.1e-20	6.4e-09	4.4e-04	4.4e-04
S ₂	5.4e-04	2.4e-06	3.9e-08	3.9e-08
	6.6e-04	1.7e-06	1.8e-08	1.8e-08
ΣV _{total} , cm ³	324.6	330.9	332.3	333.30
V _{gas} , cm ³	24.9	29.8	31.0	31.0
Basic fluid	H ₂ O >> CO ₂	CO ₂ > H ₂ O	CO ₂ > H ₂ O >> CH ₄	CO ₂ > H ₂ O >> CH ₄

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Трубка взрыва горы Намуайв

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Аннотация. Задачей проводимых исследований явилась воспроизводство термодинамических условий, необходимых для создания и существования минеральных ассоциаций в природе. Результаты исследования подтвердили современные идеи о важной, лидирующей роли температуры, давления и диоксида углерода при образовании алмазов в трубках взрыва. Результатами теоретических исследований можно предположить, что одной из причин отсутствия алмазов в трубках взрыва горы Намуайв является недостаток углерода, повышенное содержание воды и окислительные условия природной среды при их формированию.

Ключевые слова: углерод; алмаз; трубки взрыва; флюид; температура; давление; моделирование; мультисистемы.