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Petrophysical taxa of diamond deposit of Komsomolskaya kimberlite pipe (Yakutsk diamondiferous province)

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***Abstract*.** Petromagnetic and paleomagnetic studies of oriented samples from the main petrophysical taxa of the Komsomolskaya pipe diamond deposit (kimberlites, different-phase basites and terrigenous carbonate formations) were carried out in order to build a petrophysical model and solve various geological and geophysical problems on its basis: analysis of the behavior of the observed gravimagnetic field for diamond prospecting areas of geotypes 4 and 5, paleomagnetic dating of magmatic events, geodynamic reconstructions, etc. The features of the structural relationship of the petrophysical taxa of the deposit influenced the distribution of their physical properties which, as a result, affected the nature of the observed gravitational and magnetic fields. It is shown that when using vector parameters of petrophysical taxa in the "method of subtracting" potential fields from interference objects (basites of the Tunguska syneclise) it is possible to obtain a "pipe type" anomaly from the prospecting object (kimberlite pipe). In addition, based on the petrophysical model, the existence of gravimagnetic anomalies genetically related to the structures of the diatremic association - anomalies of the structural type, which should be taken into account in the process of interpreting geophysical survey data within the Yakutia diamondiferous province, was proved. Titanomagnetites have been identified as magnetization carrier minerals in dolerites, while kimberlites have a more diverse spectrum – magnetites, titanomagnetites, ilmenites and chrome spinelides. In the course of step-by-step demagnetization and subsequent component analysis of the vectors of natural residual magnetization, virtual geomagnetic poles were obtained characterizing the direction of the Earth's magnetic field at the time of introduction of kimberlites and basites. This makes it possible to establish not only the temporal sequence of tectono-magmatic events that formed the Komsomolskaya diamond deposit but also to clarify their scenario for the Yakutsk diamondiferous province as a whole. The paleomagnetic data on kimberlites of the Komsomolskaya pipe are in good agreement with the paleomagnetic data obtained on the basalts of the Upper Devonian D_3ap Appai Formation basalts (Frasnian, 385–375 Ma) and the pre-ore dike of dolerites of the Vilyuiko-Markhi intrusive complex of the Mir mine (373.5 Ma) which may indicate its relatively early age and, possibly, a deeper level of erosion section. Paleomagnetic reconstructions have shown that the epochs of kimberlite and trap formation correspond to the current position of hot spots which can be used as a basis for predicting new kimberlite fields on the Siberian platform.

Keywords: Yakutsk diamondiferous province, Alakit-Markhinskoye field, Komsomolskaya pipe, kimberlites, basites, petrophysics, palaeomagnetism, petrophysical model, petromagnetic taxa, structural type anomaly

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ГОРНОПРОМЫШЛЕННАЯ И НЕФТЕГАЗОПРОМЫСЛОВАЯ ГЕОЛОГИЯ, ГЕОФИЗИКА, МАРКШЕЙДЕРСКОЕ ДЕЛО И ГЕОМЕТРИЯ НЕДР

Научная статья
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Петрофизические таксоны месторождения алмазов кимберлитовой трубки «Комсомольская» (Якутская алмазоносная провинция)

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Резюме. Цель проведенных петро- и палеомагнитных исследований ориентированных образцов из основных петрофизических таксонов месторождения алмазов кимберлитовой трубки «Комсомольская» (кимберлиты, разнофазные базиты и терригено-карбонатные образования) заключалась в построении петрофизической модели и решении на ее основе разных геолого-геофизических задач, таких как анализ характера поведения наблюденного гравимагнитного поля для алмазопоисковых площадей четвертого и пятого геотипов, палеомагнитное датирование магматических событий, геодинамических реконструкций и пр. Особенности структурного взаимоотношения петрофизических таксонов месторождения повлияли на распределение их физических свойств, что в результате отразилось на характере наблюденных гравитационного и магнитного полей. Показано, что при использовании векторных параметров петрофизических таксонов в «методе вычитания» потенциальных полей от объектов-помех (базиты Тунгусской синеклизы) можно получить аномалию «трубочного типа» от объекта поисков (кимберлитовая трубка). Кроме того, на основе петрофизической модели доказано существование гравимагнитных аномалий, генетически связанных со структурами диатремовой ассоциации – аномалии структурного типа, которые следует учитывать в процессе интерпретации данных геофизических съемок в пределах Якутской алмазоносной провинции. В качестве минералов-носителей намагниченности в долеритах установлены титаномагнетиты, в то время как в кимберлитах их спектр более разнообразен – там встречаются магнетиты, титаномагнетиты, ильмениты и хромшпинелиды. В ходе пошаговых размагничиваний и последующего компонентного анализа векторов естественной остаточной намагниченности получены виртуальные геомагнитные полюсы, характеризующие направление магнитного поля Земли, времени внедрения кимберлитов и базитов. Это позволяет установить не только временную последовательность тектоно-магматических событий, сформировавших рассматриваемое месторождение алмазов кимберлитовую трубку «Комсомольская», но и уточнить их сценарий для Якутской алмазоносной провинции в целом. Палеомагнитные данные по кимберлитам трубки «Комсомольская» хорошо согласуются с палеомагнитными данными, полученными по базальтам аппаинской свиты верхнего девона D_3ap (фран, 385–375 млн лет) и дорудной дайки долеритов вилюйко-мархинского интрузивного комплекса рудника «Мир» (373,5 млн лет), что может свидетельствовать о ее относительно раннем возрасте и, возможно, более глубоком уровне эрозионного среза. Палеомагнитные реконструкции показали, что эпохи кимберлито- и траппообразования корреспондируются с современным положением горячих точек, что, в свою очередь, может быть положено в основу прогноза новых кимберлитовых полей на Сибирской платформе.

Ключевые слова: Якутская алмазоносная провинция, Алакит-Мархинское поле, трубка «Комсомольская», кимберлиты, базиты, петрофизика, палеомагнетизм, петрофизическая модель, петромагнитный таксон, аномалия структурного типа

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Introduction

The majority of kimberlite pipes, which had access to the day surface or were reflected by contrasting geophysical anomalies of the “pipe type”, have already been found. Prospects for the discovery of new primary diamond deposits are associated with areas within which the geological section contains thick covers of traps and/or terrigenous-sedimentary strata (2–5 diamond exploration geotypes) [1]. In these conditions, the efficiency of geochemical, mineralogical and geophysical methods is significantly reduced[1]. It is necessary to develop additional unambiguous geological and geophysical prospecting criteria and signs of control of kimberlite pipes and a reliable methodology for their identification in potential geophysical fields. The fairness of such an approach with respect to the search for primary diamond deposits in the areas characterized by complex geological and geophysical conditions is evidenced by trap "windows" and "corridors" surrounding them on their flanks [2–4][2]. It is not excluded that there may be other geophysical anomalies genetically related to the diatreme association structures – structural anomalies (SA) [5–7]. We see one of the ways to solve this problem in the integrated study of physical, petro- and paleomagnetic properties of petrophysical taxa (PPhT – structural-material complexes of a geological object characterized by certain shapes and sizes, as well as values of various physical parameters: density, electrical resistivity, magnetic susceptibility, natural residual magnetization, *Q* factor, etc.). Their volumetric distribution in the geological space forms a petrophysical model (PPhM) [8] of kimberlites, host and overlying rocks at known diamond deposits in order to build a generalizing PPhM of the indigenous diamond deposit.

The Komsomolskaya kimberlite pipe, which is located in the Daldyno-Alakitsky district of the Yakutsk diamondiferous province (YaDP) (Fig. 1), is not only an interesting object, but also allows for a systematic selection of oriented samples from the walls of the mining pit. The objectives of the complex material, physical, petro- and palaeomagnetic study of the Komsomolskaya deposit PPhT were to form on their basis:

1. A posteriori deterministic physical and geological model (PhGM) [8] as a basis for complex interpretation of the obtained materials to establish the nature of gravimagnetic anomalies for the areas of 4–5 diamond geotypes.

2. Dynamic PhGM [8] as a quantitative basis for geodynamic interpretation of paleomagnetic data: dating of kimberlite- and trap-forming processes by YaDP, paleogeographic reconstructions of the Siberian Platform for the epochs of tectono-magmatic activation [9], forecasting of mineral deposits, etc.

Materials and methods

The Daldyno-Alakitsky district, to which the Komsomolskaya kimberlite pipe diamond deposit is confined, is located in the area of juxtaposition of two large structures of the Siberian Platform: the Anabar Anteclise and the Tunguskaya Syneclise (Fig. 1, *a*). The pipe was discovered in 1974 by geologists of the Amakinskaya expedition G.B. Balandina, I.Ya. Bogatykh, M.G. Kontareva, I.V. Lashkevich, V.I. Stegniy, I.K. Sarychev during prospecting drilling works on a 500×500 m grid.

The Komsomolskaya diamond deposit [10–12][3] belongs to the 5th prospecting geotype (Fig. 1, *b, c*) – an area of predominant development of highly magnetic eruptive rocks in the upper part of the geological section (up to 250 m). Carbonate rocks of the Oldondin ($Є_3$-O_1ol), Sokhsolokh ($O_{1\text{-}2}$sh), Kylakh ($O_{2\text{-}3}$kl) formations and Landover (S_1ln) stage (Fig. 1, *d*) serve as a host frame (carbonate basement) for kimberlites of the Daldyno-Alakisky intrusive complex of the Middle Paleozoic age (íD_3-C_1dl). According to the content of petrogenic oxides such as FeO_{tot} (7–11.5 %) and TiO_2 (2–3.2 %) kimberlites of the Komsomolskaya pipe belong to petrochemical type 3 (magnesian-iron, high-titanic, low-potassium), which is consistent with the relatively high content of ilmenite. The studied deposit has an elongated shape with isometric extension approximately in the central part. Its long axis is orientated in the north-eastern direction along the azimuth of 65°. The deposit is composed of two types of kimberlites:

[1] Serov I.V., Grakhanov O.S., Koshkarev D.A., Ageenkov E.V., Boyarov V.M., Gerasimchuk A.V., et al. *Forecasting and prospecting of primary diamond deposits on the Siberian platform: Methodological manual.* Mirny: ALROSA; 2020, 155 p. (In Russ.) / Серов И.В., Граханов О.С., Кошкарев Д.А., Агеенков Е.В., Бояров В.М., Герасимчук А.В. [и др.] Прогнозирование и поиски коренных месторождений алмазов на Сибирской платформе: методическое пособие / под ред. А.В. Толстова. Мирный: Изд-во АЛРОСА, 2020. 155 с.

[2] Nikulin V.I., Lelyukh M.I., Von-der-Flaass G.S. *Almazoprognostka (methodical manual)*. Irkutsk: ALROSA; 2002, 320 p. (In Russ.) / Никулин В.И., Лелюх М.И., Фон-дер-Флаасс Г.С. Алмазопрогностика (методическое пособие). Иркутск: Изд-во АЛРОСА, 2002. 320 с.

[3] Kostrovitsky S.I., Spezicius Z.V., Yakovlev D.A., Von-der-Flaass G.S., Suvorova L.F., Bogush I.N. Atlas of root diamond deposits of the Yakutsk kimberlite province. Mirny: ALROSA, 2015, 480 p. (fig. 475, tab. 125). (In Russ.) / Костровицкий С.И., Специус З.В., Яковлев Д.А., Фон-Дер-Флаасс Г.С., Суворова Л.Ф., Богуш И.Н. Атлас коренных месторождений алмазов Якутской кимберлитовой провинции. Мирный: Изд-во АЛРОСА, 2015. 480 с. (рис. 475, табл. 125).

– flanked by a dyke of coherent kimberlite (CK) of northeastern strike of the early phase of emplacement;

– in the centre, a diatreme of pyroclastic kimberlite (PK) of the late intrusion phase.

The age of the deposit is ambiguous (Table 1). According to isotopic studies and taking into account geological materials, the time of formation of the kimberlite pipe can refer to both the Late Silurian-Early Devonian (S_2-D_1) and Late Devonian-Early Carboniferous epoch (D_3-C_1).

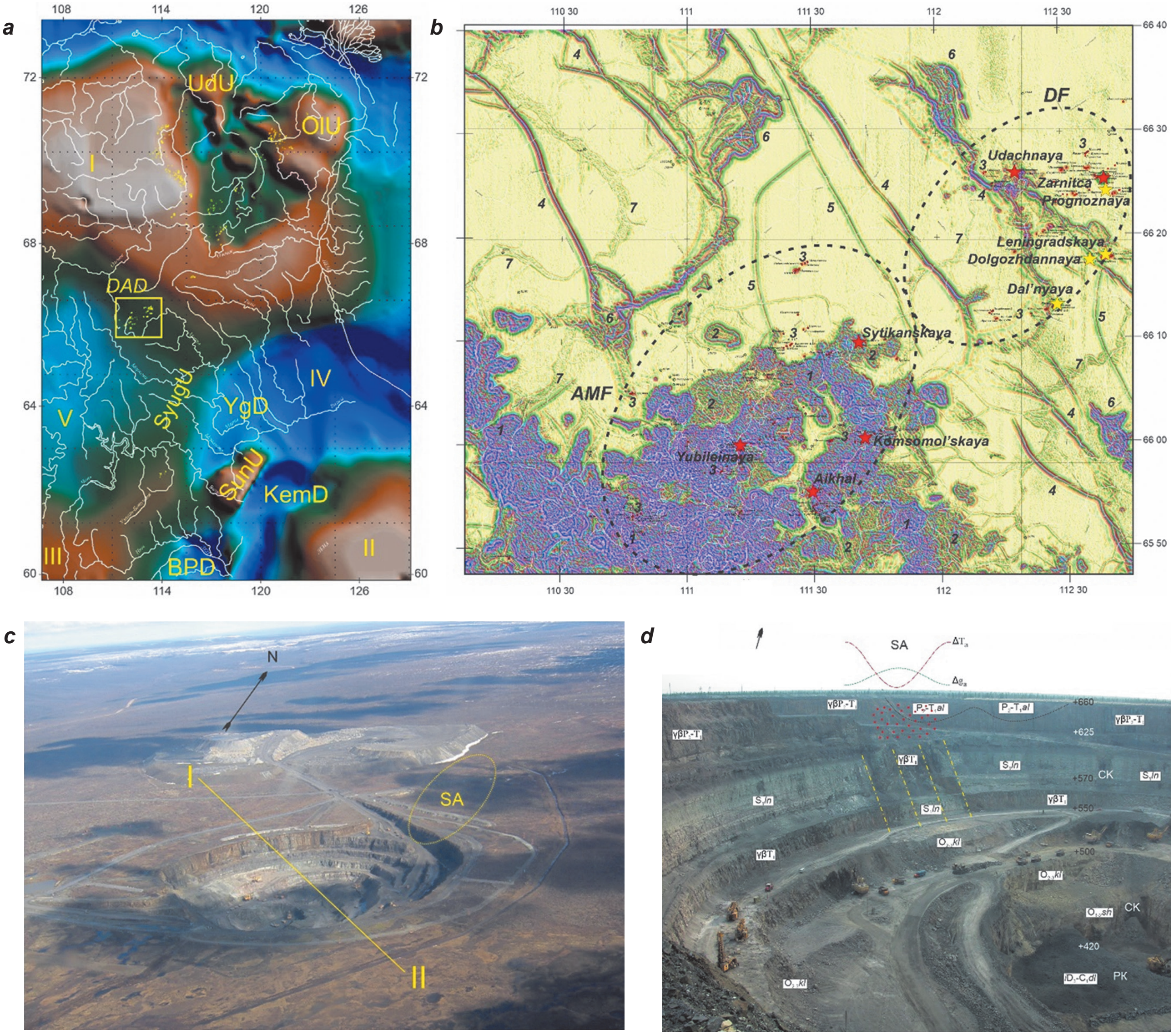

Fig. 1. Work area:
a – location of the Daldyno-Alakitsky area (rectangle) on the tectonic scheme of the eastern part of the Siberian platform. Basement structures of the Siberian Platform: first order – anteclises (I – Anabarskaya, II – Aldanskaya, III – Nepa-Botuoba), syneclises (IV – Vilyuiskaya, V – Tunguskaya); the second order – uplifts (SunU – Suntarskoe, OlU – Olenekskoe, UdU – Udzhinskoe, SyugU – Sugdzherskoe), depressions (BPD – Baikal-Patom, KemD – Kempendyayskaya, YgD – Ygyattinskaya); b – position of the studied kimberlite bodies on the summary map of the local component of the magnetic field ΔT_{loc} (red/yellow asterisk indicate known diamond deposits/off-balance ores). Mapping of igneous formations: 1, 2 – sills of trap intrusions reserving watersheds: 1 – Olenek-Velingninskiy and Katangsky intrusive complexes (non-separated), 2 – Kuzmovsky intrusive complex; 3 – kimberlite pipes; 4 and 5 – positively and negatively magnetized dolerite dykes of the Vilyuisko-Kotuiskaya fault zone (supply channels); 6 – near-dyke transgressive and sublayer dolerite intrusions; 7 – accumulation zones of trap formation destruction products in the floodplains of watercourses. AMF and DF are Alakit-Markhinskoe and Daldynskoe kimberlite fields, respectively; c – aerial view of the Komsomolskaya pipe open-pit; d – geological section along the line I–II (see c): CK – coherent kimberlite; PK – pyroclastic kimberlite; red dots – petromagnetic heterogeneities of the firing zone; yellow dash-dotted lines indicate the zone of increased fracturing; Δg_a and ΔT_a indicate geophysical anomalies of the gravitational and magnetic fields respectively; SA – structural type anomaly and its contour; Arabic numerals stand for the absolute mark of the open-pit horizon

Рис. 1. Район работ:
a – положение Далдыно-Алакитского района (прямоугольник) на тектонической схеме восточной части Сибирской платформы. Структуры фундамента Сибирской платформы: первый порядок – антеклизы (I – Анабарская, II – Алданская, III – Непско-Ботуобинская), синеклизы (IV – Вилюйская, V – Тунгусская); второй порядок – поднятия (SunU – Сунтарское, OlU – Оленекское, UdU – Уджинское, SyugU – Сюгджерское), впадины (BPD – Байкало-Патомская, KemD – Кемпендяйская, YgD – Ыгыаттинская); b – положение изученных кимберлитовых тел на сводной карте локальной составляющей магнитного поля $\Delta T_{лок}$ (красная/желтая звездочка – известные месторождения алмазов/забалансовые руды). Картирование магматических образований: 1, 2 – силлы трапповых интрузий, бронирующих водоразделы: 1 – оленек-велингнинский и катангский интрузивные комплексы (неразделенные), 2 – кузьмовский интрузивный комплекс; 3 – кимберлитовые трубки; 4 и 5 – положительно и отрицательно намагниченные дайки долеритов Вилюйско-Котуйской зоны разломов (подводящие каналы); 6 – околодайковые секущие и субпластовые интрузии долеритов; 7 – зоны аккумуляции продуктов разрушения трапповых образований в поймах водотоков. AMF и DF – Алакит-Мархинское и Далдынское кимберлитовые поля соответственно; c – вид карьера трубки «Комсомольская» с воздуха; d – геологический разрез по линии I–II (см. c): CK – когерентный кимберлит; PK – пирокластический кимберлит; красные точки – петромагнитные неоднородности зоны обжига (петромагнитные неоднородности 2 типа); желтые штрих-пунктирные линии – зона повышенной трещиноватости; Δg_a и ΔT_a – геофизические аномалии гравитационного и магнитного полей соответственно; SA – аномалия структурного типа и ее контур; арабские цифры – абсолютная отметка горизонта карьера

Table 1. Absolute age of kimberlites from the diamond deposit of the Komsomolskaya kimberlite pipe
Таблица 1. Абсолютный возраст кимберлитов месторождения алмазов кимберлитовой трубки «Комсомольская»

No.	Type and variety of rock [source]	Method	Age, millions of years, Ma	Epoch
1	Pyroclastic kimberlite [13]	Rb-Sr	411±2	S_2-D_1
2		Rb-Sr	420±1	S_2-D_1
3		Rb-Sr	410±8	S_2-D_1
4		Rb-Sr	416±1	S_2-D_1
5	Kimberlite [14]	Rb-Sr	358	D_3-C_1
6	Kimberlite, zircon [15]	U-Pb	358	D_3-C_1

The deposit is overlain by a low thickness (up to 3 m) of terrigenous sediments of the Carboniferous Aikhal Formation (C_{2-3}ah) (Fig. 2, *a*). In addition, the deposit is armoured by traps belonging to two late volcanic phases of basite magmatism of the eastern side of the Tunguskaya syneclise (the first, second, and third phases correspond to the Olenek-Velingninsky, Katangsky and Kuzmovsky intrusive complexes of the Vilyui sheet series)[4]: the second phase (β_0-$\gamma\beta P_2$-T_1) and the third phase ($\gamma\beta T_1$) [3, 16], with a total thickness (above the pipe) of about 65 m (see Fig. 1, *d*). Sills of the studied phases are composed of different petrographic types of dolerites and differ in the content of Fe_2O_3, TiO_2, etc. oxides (Fig. 3, *a*).

The dolerite sill of the second phase ($\gamma\beta P_2$-T_1) and co-magmatic lenses of tuffs of the Alakit Formation (P_2-T_1al) armour the daytime surface lying subhorizontally on the rocks of the Aikhal Formatio (see Fig. 1, *d*). The dolerite sill of the third phase ($\gamma\beta T_1$) forms a scarp during the transition from the lower horizon (O_{2-3}kl and S_1ln boundary) to the upper horizon (to the bottom of the fluorine phase traps) thereby cutting off the northwestern block of the diatreme to form a kimberlite detached mass (Fig. 2, *b, c*; 4, *d*). The peculiarity of basites of the second and third phases of the Komsomolskaya deposit [16], in contrast to the previously studied deposits Aikhal, Sytykanskaya and Yubileinaya [17], is that they were formed in the epochs of, respectively, direct (N) and reverse (R) polarity of the Earth's magnetic field [6, 18], when the Siberian platform occupied a high latitudinal palaeogeographic position [9]. According to [19], the deposit in terms of geological and geophysical complexity belongs to the third variant of the prospecting situation, which is the most difficult for the detection of diamond deposits by gravimagnetic anomalies (Fig. 4, *a, b, d*).

[4] Salikhov R.F., Salikhova V.V., Ivanyushin N.V., Okhlopkov V.I. State geological map of the Russian Federation at a scale of 1:200000, Verkhnevilyuyskaya series (second edition). Sheet Q-49-XXI, XXII (Aikhal). Explanatory note. Saint Petersburg; 2005, 284 p. / Салихов Р.Ф., Салихова В.В., Иванюшин Н.В., Охлопков В.И. Государственная геологическая карта Российской Федерации масштаба 1:200000, Верхневилюйская серия (издание второе). Лист Q-49-XXI, XXII (Айхал). Объяснительная записка. СПб.: 2005. 284 с.

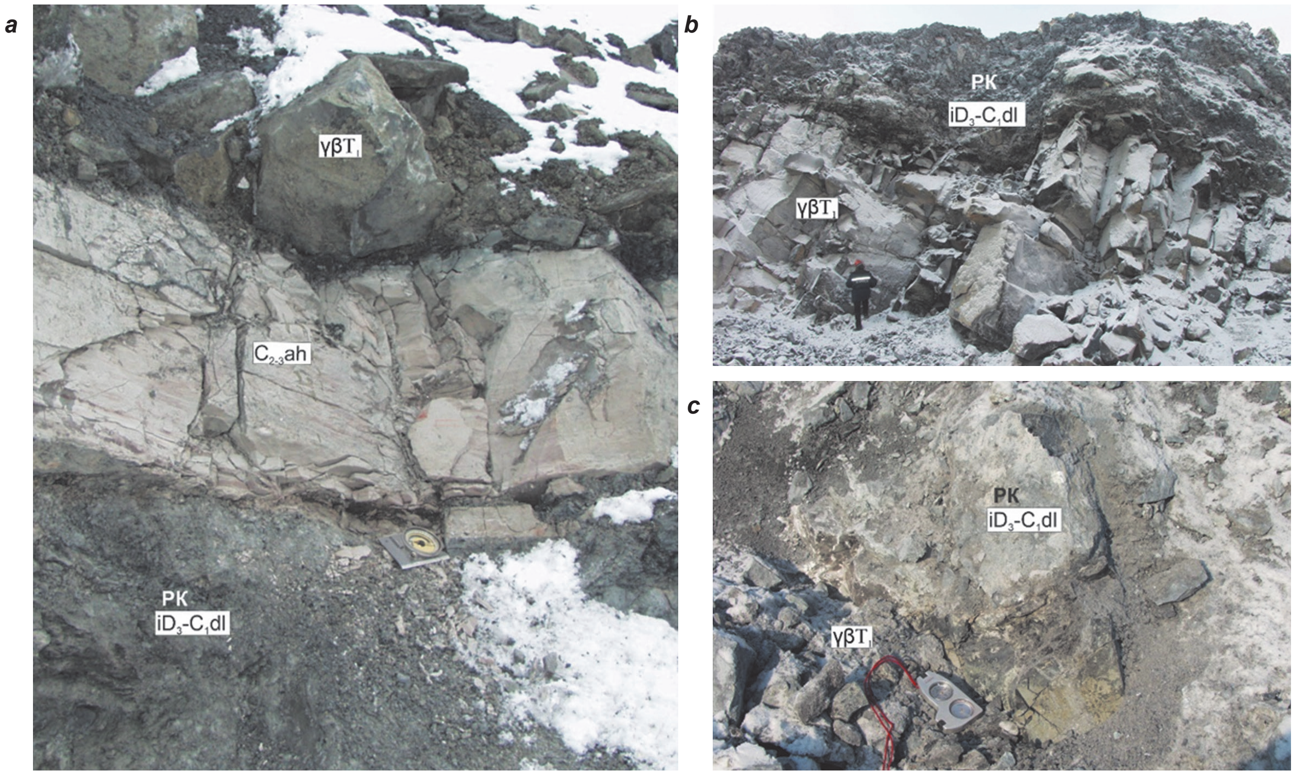

Fig. 2. Relationships between petrophysical taxa of the Komsomolskaya pipe:
a – kimberlites and overlying terrigenous sedimentary rocks of the Aikhal Formation and dolerite sill of the third phase; b – kimberlite detachment; c – fragment of the contact between kimberlites and the third phase dolerites

Рис. 2. Характер взаимоотношений петрофизических таксонов трубки «Комсомольская»:
а – кимберлитов и перекрывающих их терригенно-осадочных пород айхальской свиты и силла долеритов третьей фазы; b – кимберлитовый отторженец; с – фрагмент контакта кимберлитов и долеритов третьей фазы

$^{40}Ar/^{39}Ar$ geochronological studies of dolerites by the step heating method [20] performed at the V.S. Sobolev Institute of Geology and Mineralogy, Siberian Branch of the Russian Academy of Sciences. V.S. Sobolev Institute of Geology and Mineralogy SB RAS (Novosibirsk) showed that the introduction of sills corresponds to the Permo-Triassic period (Table 2) but directly contradict the sequence of magmatic events established in the course of geological studies [3, 16].

Table 2. Results of $^{40}Ar/^{39}Ar$ isotopic dating of dolerite sills from the diamond deposit of the Komsomolskaya kimberlite pipe
Таблица 2. Результаты изотопного $^{40}Ar/^{39}Ar$ датирования силлов долеритов месторождения алмазов кимберлитовой трубки «Комсомольская»

T, °C	*t*, min	^{40}Ar, 10^{-9} cm^3 STP	$^{40}Ar/^{39}Ar$	±1*σ*	$^{40}Ar/^{39}Ar$	±1*σ*	$^{40}Ar/^{39}Ar$	±1*σ*	$^{40}Ar/^{39}Ar$	±1*σ*	Ca/K	$\Sigma^{39}Ar$, %	Age, Ma	±1*σ*
Dolerites of the Kuzmovsky intrusive complex – the third phase ($\gamma\beta T_1$), sample K-3 (21.35 mg)														
J = 0.005416±0.000077; total age = 297±4.5 Ma														
650	10	4.9	37.6	0.501	0.036	0.01071	0.2	0.04	0.0001	0.01322	0.7	2.9	334.2	32.3
800	10	44.5	38.4	0.072	0.022	0.00148	15.3	0.6	0.019	0.00197	55	28.2	295	6.2
900	10	35.8	37.1	0.073	0.025	0.00148	15.9	0.4	0.0221	0.00211	57.3	49.4	276.4	6.4
1000	10	34	37.9	0.059	0.019	0.00166	9	0.5	0.0142	0.00151	32.39	69.1	302.3	5.4
1130	10	54.3	38.5	0.049	0.017	0.00103	1.2	0.5	0.0147	0.00109	4.36	100	305.7	4.8
Dolerites of the Katangsky intrusive complex – the second phase (β_0-$\gamma\beta P_2$-T_1), sample K-2 plagioclase (35.31 mg)														
J = 0.005402±0.000076; total age = 255±4.3 Ma														
650	10	4.3	20.2	0.149	0.073	0.00856	3.2	2.4	0.005	0.00637	11.4	3.1	174	16.9
800	10	26.6	28.7	0.063	0.026	0.00171	20.8	0.8	0.0053	0.00227	74.7	16.8	246.9	6.6
950	10	111.7	29.4	0.035	0.017	0.00029	17.8	0.1	0.0018	0.00157	64.1	72.8	270.4	5.3
1500	10	27.5	30.2	0.065	0.025	0.00153	15.5	0.4	0.0017	0.00225	55.94	86.2	268.7	6.6
1150	10	30.5	32.5	0.074	0.024	0.00137	6.3	0.5	0.0194	0.0022	22.84	100	243.8	6.4

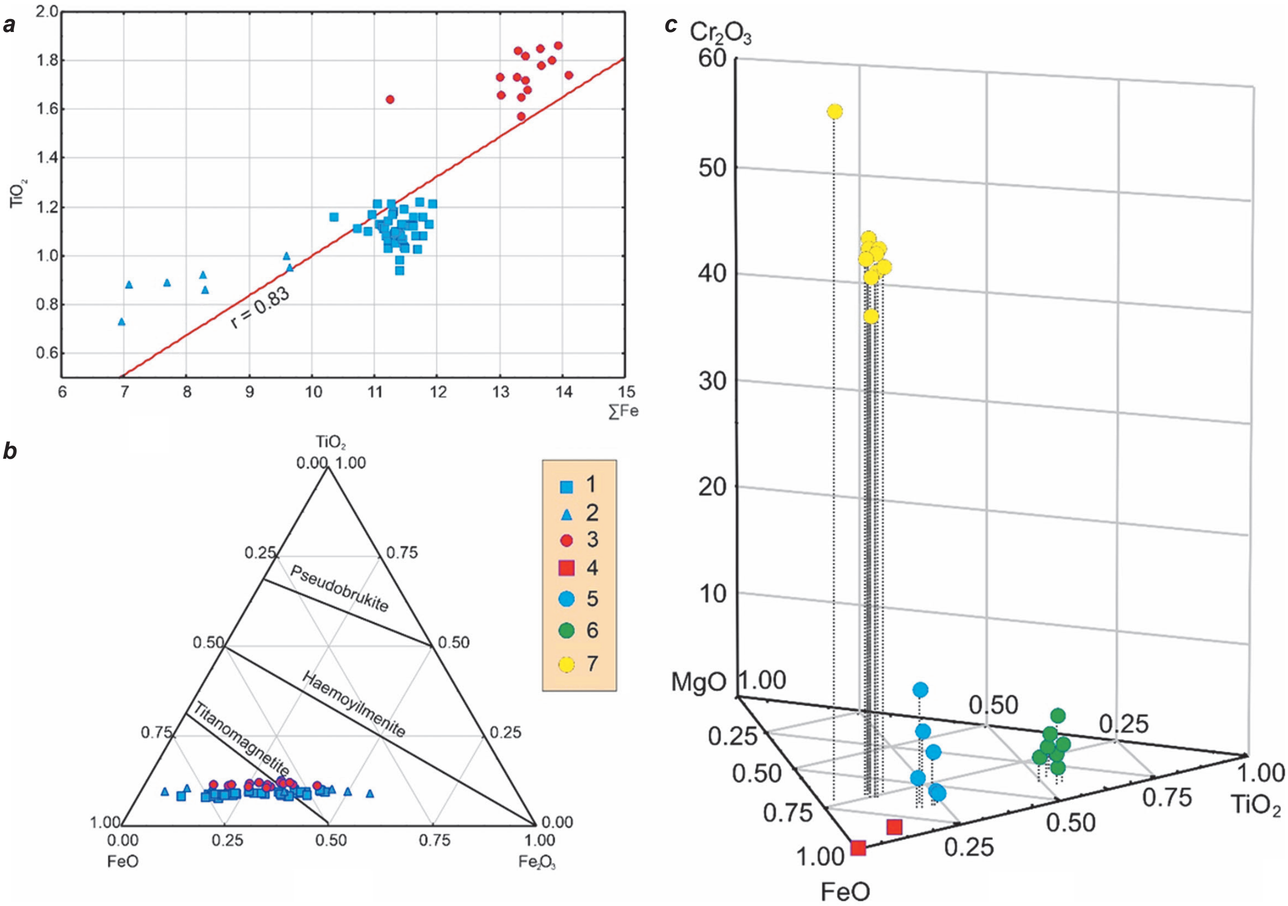

Fig. 3. Chemical composition of magnetisation carrier minerals of the Komsomolskaya pipe:
a, b – basites by [16] (1/2 – dolerites/tuffs of the second phase, 3 – dolerites of the third phase);
c – kimberlites[3] (4 – magnetites, 5 – titanomagnetites, 6 – Ilmenite, 7 – chromospinelides)
Рис. 3. Химический состав минералов-носителей намагниченности трубки «Комсомольская»:
a, b – базиты по источнику [16] (1/2 – долериты/туфы второй фазы, 3 – долериты третьей фазы);
c – кимберлиты[3] (4 – магнетиты, 5 – титаномагнетиты, 6 – ильмениты, 7 – хромшпинелиды)

According to the geochemical classification $FeO – Fe_2O_3 – TiO_2$ [21], all magnetisation carriers of the Permo-Triassic basites Daldyno-Alakitsky district, despite the marked differences in the chemical composition of the studied embedding phases, belong to the same titanomagnetite series (Fig. 3, *b*). This conclusion agrees well with the results of independent differential thermomagnetic analysis of basites [16].

Thus, the Komsomolskaya pipe is a unique object for establishing petrophysical, geological-geophysical and other prospecting criteria and developing, on their basis, an optimal set of geological and geophysical methods for prospecting for primary diamond deposits within the eastern side of the Tunguskaya syneclise (4 and 5 diamond prospecting geotypes of areas). In this regard, the study of the structure and distribution of physical properties of PPhT of the Komsomolskaya deposit is an urgent task of the present research in order to form its PhGM and develop on its basis a methodology for correct geological interpretation of gravimagnetic exploration materials, geodynamics, mineralogy, etc.

A total of 30 outcrops (sites) were studied in the quarry from which 334 samples were collected (Fig. 2; 5). The studied rocks of the Komsomolskaya pipe deposit are classified into seven PPhT. The most representative is the collection of basites (dolerites and tuffs), as the data on them are important for solving a wide range of problems: petromagnetic mapping, interpretation of observed geophysical fields, etc. The collection of kimberlites is the most representative. For kimberlites, the representativeness of the sample is smaller, but it is sufficient for constructing a correct PPhM [19]. The relatively small number of samples from terrigenous sedimentary rocks is explained by the fact that their magnetic properties are weak and do not significantly affect the character of the anomalous field. At the same time the physical properties of the carbonate basement are well

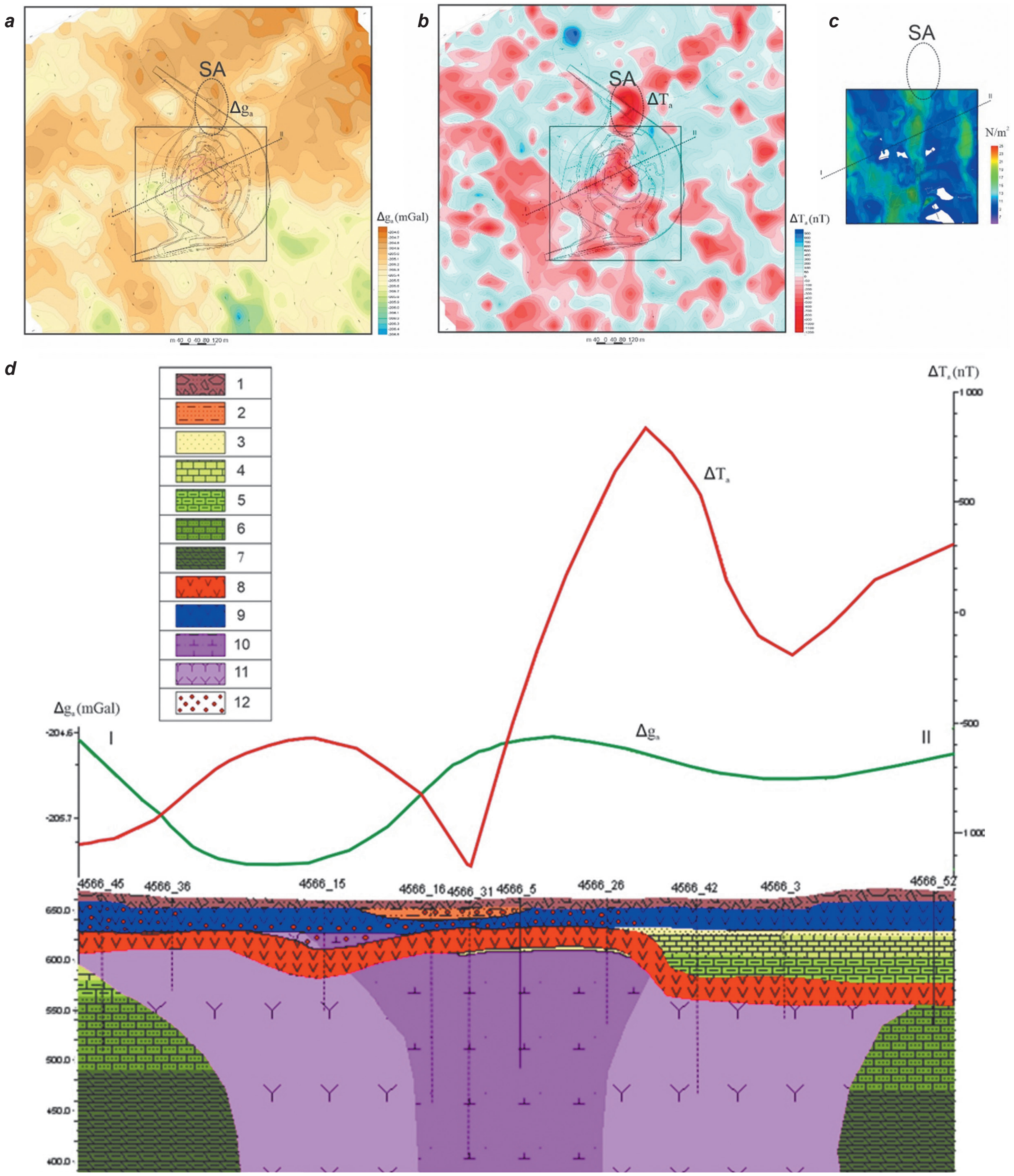

Fig. 4. A posteriori deterministic physical-geological model of the diamond deposit of the Komsomolskaya kimberlite pipe:

a, b – maps of anomalous fields: a – gravitational, b – magnetic; c – distribution of the crack density parameter (the distribution of isolines is shown starting from the value of 10 cracks per m²); d – geological and geophysical section along the line I–II (1 – modern eluvial-deluvial deposits Q_4; 2 – Alakit Formation P_2-T_1al, tuffs and tuff-sandstones (second phase); 3 – $C_{2\text{-}3}ah$ – Aikhal Formation, siltstones and sandstones; 4–7 – rocks of the host complex (carbonate basement): 4 – S_1ln – Landoverian stage, limestones and dolomites, 5 – $O_{2\text{-}3}kl$ – Kylakh Formation, limestones, 6 – $O_{1\text{-}2}sh$ – Sokhsolokh Formation, limestones, 7 – Є$_3$-O_1ol – Oldondinskaya Formation, limestones; 8 and 9 – Permian-Triassic traps: 8 – negatively magnetized dolerite sill $\gamma\beta T_1$ of the Kuzmovsky intrusive complex (third phase), 9 – positively magnetized dolerite sill $\gamma\beta P_2$-T_1 of the Katanga intrusive complex (second phase); 10 and 11 – Daldyno-Alakitsky intrusive complex iD_3-C_1dl: 10 – pyroclastic kimberlite, diatreme (late phase), 11 – coherent kimberlite, dyke (early phase); 12 – petromagnetic heterogeneities of the firing zone (2 geotype petromagnetic heterogeneities)

For other explanations, see Fig. 1

Рис. 4. Апостериорная детерминированная физико-геологическая модель месторождения алмазов кимберлитовой трубки «Комсомольская»:
*a, b – карты аномальных полей: a – гравитационного, b – магнитного; c – распределение параметра плотности трещин (показано распределение изолиний, начиная с величины 10 трещин/м^2); d – геолого-геофизический разрез по линии I–II (1 – современные элювиально-делювиальные отложения Q_4; 2 – алакитская свита P_2-T_1al, туфы и туфо-песчаники (вторая фаза); 3 – $C_{2-3}ah$ – айхальская свита, алевролиты и песчаники; 4–7 – породы вмещающего комплекса (карбонатный цоколь): 4 – S_1ln – ландоверский ярус, известняки и доломиты, 5 – $O_{2-3}kl$ – кылахская свита, известняки, 6 – $O_{1-2}sh$ – сохсолохская свита, известняки, 7 – $Є_3$-O_1ol – олдондинская свита, известняки; 8 и 9 – траппы пермотриаса: 8 – отрицательно намагниченный силл долеритов $γβT_1$ кузьмовского интрузивного комплекса (третья фаза), 9 – положительно намагниченный силл долеритов $γβP_2$-T_1 катангского интрузивного комплекса (вторая фаза); 10, 11 – далдыно-алакитский интрузивный комплекс $íD_3$-C_1dl: 10 – пирокластический кимберлит, диатрема (поздняя фаза), 11 – когерентный кимберлит, дайка (ранняя фаза); 12 – петромагнитные неоднородности зон обжига (петромагнитные неоднородности 2 геотипа))
Другие пояснения см. на рис. 1*

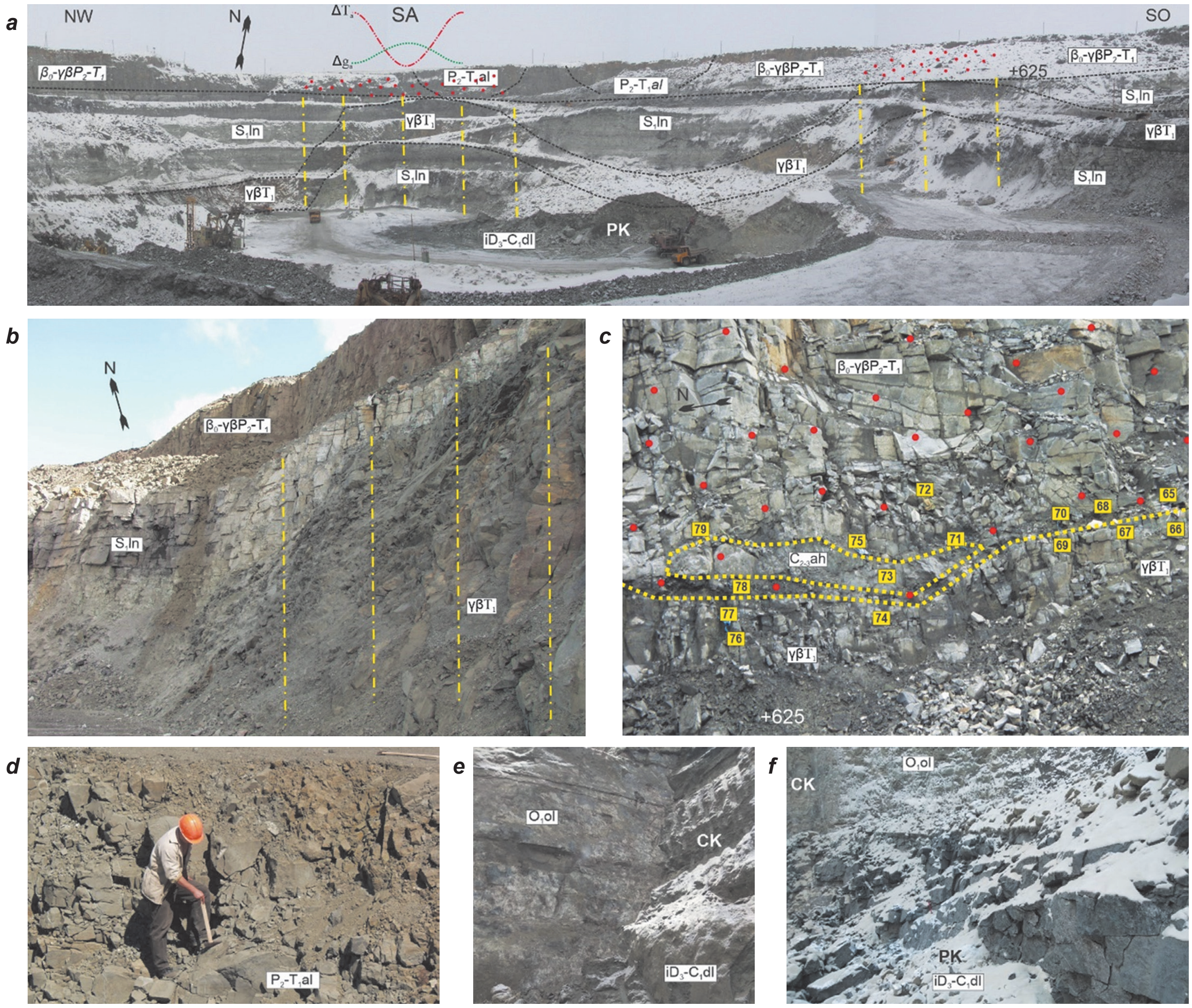

Fig. 5. Sampling in the open pit of the diamond deposit of the Komsomolskaya kimberlite pipe:
*a – view of the north-eastern side of the open pit; b –sills of the second and third phase dolerites; c – contact of two phases of dolerite sills (outcrop 5); d – tuffs of the Alakit Formation; e – dyke of coherent kimberlites; f – main body of pyroclastic kimberlites
Yellow dashed-dotted lines indicate the zone of increased fracturing; red dots indicate petromagnetic heterogeneities of 2(5) type; yellow squares indicate the location of the studied samples (number)*

Рис. 5. Отбор образцов в карьерном поле месторождения алмазов кимберлитовой трубки «Комсомольская»:
*a – вид северо-восточного борта карьера; b – силлы долеритов второй и третьей фазы; c – контакт двух фаз силлов долеритов (обнажение 5); d – туфы алакитской свиты; e – дайка когерентных кимберлитов; f – основное тело пирокластических кимберлитов
Желтые штрих-пунктирные линии – зона повышенной трещиноватости; красные точки – петромагнитные неоднородности 2(5) типа; желтые квадраты – положение изученных образцов (цифра)*

enough studied at the neighbouring objects (Aikhal, Yubileinaya pipes, etc.) [22, 23].

Oriented stufs were selected in the modern coordinate system using a mountain compass (selection of strongly magnetic rocks was carried out with constant control of magnetic declination, additionally spatial landmarks with known surveyor's reference were used) [9]. For this purpose we selected ledges in the quarry walls with rock occurrence undisturbed by blasting (Fig. 2; 5). In general the studied interval was >400 m: from hill. 650 to hills. 235 (hereinafter absolute elevations are given) (see Fig. 1, *d*). At least 3 cubes with a 20 mm rib were sawed out of the sample. As a result, more than 1250 cubes were studied.

The complex of studies of kimberlites included:

Petrophysical studies characterizing the gravitational and magnetic state of rocks *in situ*. The studies are based on the bulk density σ, natural remanent magnetisation (NRM) vectors *In*, inductive magnetisation $Ii = æH$ (where *H* is the vector of the Earth's magnetic field strength in the study area) and total magnetisation $Is = Ii+In$, which determine the type of the anomalous magnetic field above the kimberlites. In turn, the magnetisation vectors (*In*, *Ii* or *Is*) are defined in space by three components: magnitude (*In*, *Ii* and *Is*, respectively), declination ($0 < D < 360°$) and inclination ($-90° < J < 90°$) [9]. The *In/Ii* ratio characterises the Königsberger coefficient (*Q* factor), which is usually 0.3–0.6 units for YaDP kimberlites [17, 24–26].

Magneto-texture analysis, which is based on measurements of the anisotropy of magnetic susceptibility æ (AMS) of oriented samples. From the AMS tensors (long K_1, middle K_2 and short K_3 axes of the ellipsoid) according to the formulae given in [27], the parameters were calculated:

– refined degree of anisotropy

$$P_J = \exp\sqrt{\{2[(\eta_1-\eta_m)^2+(\eta_2-\eta_m)^2+(\eta_3-\eta_m)^2]\}},$$

where $\eta_1 = lnK_1$; $\eta_2 = 1nK_2$; $\eta_3 = 1nK_3$; $\eta_m = (\eta_1 + \eta_2 + \eta_3)/3$;

– lineation $P_1 = L = \frac{K_1}{K_2}$;

– plane $P_3 = F = \frac{K_2}{K_3}$;

– grain shape $T = \left[\frac{2\ln(K_2/K_3)}{\ln(K_1/K_3)}\right] - 1$.

Flattened bodies have values $0 < T \leq 1$, whereas negative values $-1 \leq T < 0$ are characteristic of elongated bodies. For neutral grains, resembling the so-called plano-deformed ellipsoids in shape, $T \rightarrow 0$. The long K_1 and middle K_2 axes of the AMS ellipsoid form the magnetic stratification plane along which the matter moves: a relatively increased velocity (more than 0.01 m/s) will be observed along the K_2 axis, and a decreased velocity along the K_1 axis.

The AMS of different-phase dolerite sills in outcrops was studied in detail: 1 and 20 – second phase; 4 and 7 – third phase; 3, 5 and 19 – PMHs of 2 and 5 geotypes (Fig. 6).

Magneto-structural analysis was carried out to determine the hysteresis parameters of ferrimagnetic minerals of kimberlites: the values of specific magnetic saturation moment (Ms), coercive force (Bc) from the inductive magnetisation curve and determination of the values of specific magnetic moment of residual saturation (Mrs) and its destructive field (Bcr) [28, 29]. To increase the accuracy of the obtained values of hysteresis parameters, corrections for the background of paramagnetic minerals were introduced into the graphs.

Thermomagnetic analysis allows us to determine the component chemical composition of ferrimagnetics by Curie points (Θ) on the graphs of the dependence $æ = f(T)$ on the basis of the Hopkinson effect (the Hopkinson effect is a sharp increase in the magnetic susceptibility of magnetic materials in weak magnetic fields near their Curie point, due to a sharp decrease near this temperature in the magnetic anisotropy of the materia). Two heating cycles were used to study the magnetisation carrier minerals. The method of stepwise demagnetisation by temperature was substantiated on the basis of the data of thermomagnetic analysis.

Paleomagnetic studies of the component composition of NRM vectors [9]. Samples of kimberlites (CK and PK) were subjected to laboratory experiments on demagnetisation by an alternating magnetic field and temperature. The characteristic components In^{ch} of kimberlites were taken along straight lines passing through at least three points and the centre of the Zijderveld diagram [30]. In complicated cases the joint analysis of single directions and remagnetisation circles was used [31]. The resulting statistics included data on one sample from each piece which underwent stepwise demagnetisation by temperature or alternating magnetic field.

Petrographic and geochemical studies were carried out to study the composition of minerals of the ferrimagnetic fraction of kimberlites and

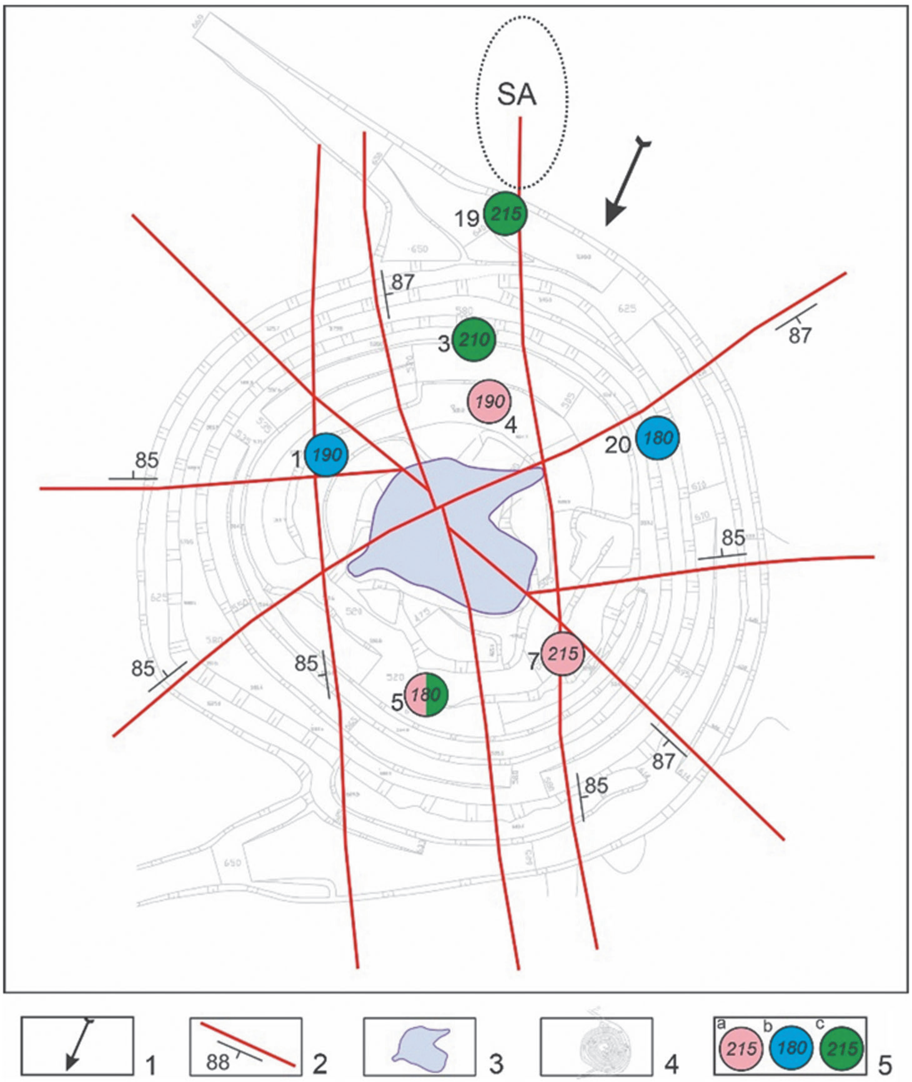

Fig. 6. Diagram of the fault-block structure of the localization area of the Komsomolskaya pipe with the elements of the magnetic texture of dolerite sill "flow" that reserve the Komsomolskaya pipe deposit [9]:
1 – estimated direction of sill movement; 2 – faults and their occurrence elements;
3 – ore body contour; 4 – open-pit bench; 5 – blue/red and green circles – dolerites of the second/third phase and petromagnetic heterogeneities of 2(5) type, respectively, the number inside the circle indicates the azimuth of the long axis of the magnetic susceptibility anisotropy ellipsoid (K_1), the number next to the circle is the outcrop number
For further explanations, see below.

Рис. 6. Схема разломо-блокового строения участка локализации трубки «Комсомольская» с элементами магнитной текстуры «течения» силлов долеритов, бронирующих месторождение трубки «Комсомольская» [9]:
1 – предполагаемое направление движения силлов; 2 – разломы и элементы их залегания;
3 – контур рудного тела; 4 – уступы карьера; 5 – синий/красный и зеленый кружок – долериты второй/третьей фазы и петромагнитные неоднородности 2(5) типа соответственно, число внутри кружка обозначает азимут длинной оси эллипсоида анизотропии магнитной восприимчивости (K_1), цифра рядом с кружком – номер обнажения
Другие пояснения см. ниже по тексту

basites according to generally accepted methods [21, 30–34].

Apparatus and equipment. Laboratory researches were carried out on modern apparatus and equipment: Camebax-micrho microprobe, scanning microscope JSM-6480LM, X-ray tomograph V/tome/ XS 240 Phoenix GE, high-resolution autoemission electron microscope TESCAN MIRA 3 LMU series, scales VMK 4001, multifunctional magnetic susceptibility meter MFK1-FA, spin-magnetometer JR-6, demagnetising units with alternating magnetic field AF-Demagnetizer and LDA-5 and temperature MMTD80A, vibro-magnetometers and magnetic fraction meters, etc.

Material processing and interpretation. The obtained factography (sampling schemes, measurement and experimental data, analyses, etc.) was summarised in the “RESEARCH” database [35].

During the studies we used domestic and foreign methodological developments on graphic and analytical implementation of solutions of petro- and palaeomagnetic problems using the computer programs Statistica-6 [36], Enkin-96 [37], Anisoft-42 [38], OPAL-3 [39], PetroStat and AMSStat [35].

To solve the set task of physical and geological modelling, ModelVisionPro-17.5 (MVP-17.5) software (Encom Technology, Australia) was used, which allows building geological models and comparing their simulated characteristics with field observation data. MVP-17.5 automates the forward and backward modelling process, which allows to verify the decision on the suitability of a particular PhGM as well as to predict some properties of its constituent PPhTs. The software is a 3D shell that can be used to create simple geological models, with a high level of performance, or complex models with a large number of objects.

Results and discussion

At the stage of laboratory works the spectrum of values of physical parameters of PPhT, which are the constituent elements of PPhM of the Komsomolskaya deposit, was obtained (Table 3; Fig. 7). Subsequent paleomagnetic and magneto-mineralogical analyses revealed the nature of their magnetisation.

PPhT-1, which includes unaltered host rocks of the carbonate basement of the Early Palaeozoic – silt-sandstones and limestones of the Oldondin ($Є_3$-O_1ol), Sokhsolokh (O_{1-2}sh), Kylakh (O_{2-3}kl) formations and Landover (S_1ln) stage (Fig. 1, *d*; 4, *d*), characterised by bulk density σ = 2600±43 kg/m^3, magnetic susceptibility æ < 10·10^{-5} SI, NRM *In* < 5·10^{-3} A/m and factor *Q* < 0.2 (i.e. practically non-magnetic formations) (Table 3; Fig. 7). The directions of NRM vectors are clustered in northern rhumbas *Dm* ≈ 353° with a gentle inclination *Jm* ≈ 18°. The average values are quite similar to the host rocks of the carbonate basement of the Nyurbinskaya pipe [22]. In the zones of “firing” (PMHs of type 2) with kimberlites and dolerites of the third phase of embedding, the inclinations of NRM vectors become negative in the 1st and 3rd sectors of the stereogram, respectively: *D* = 61° and *J* = -20°, *D* = 284° and *J* = -65°.

PPhT-2 (CK) and PPhT-3 (PK) represent objects of geological and geophysical prospecting – primary diamond deposits (Fig. 1, *d*; 5, *e*, *f*). Their bulk density varies from 2300 to 2500 kg/m^3, slightly increasing with depth (see Table 3; Fig. 7). Magnetic characteristics of the studied kimberlites are elevated, relative to sedimentary PPhT-1 and PPhT-4, but have a number of peculiarities.

According to the results of petrochemical studies in kimberlites there are several minerals-carriers of magnetisation: Magnetite – Mgt, Titanomagnetite – Timt, Ilmenite – Ilm and Chromospinelide – ChSp (Fig. 3, *c*)[3]. In (Table 4; Fig. 8), the results of chemical and magneto-mineralogical studies of fine-medium porphyry kimberlite (sample kom16-04) are presented. Curie points highlighted on the thermomagnetogram æ during heating (Fig. 8, *b*) correspond to the minerals Mgt (≈560 °C) and Ilm (≈400 °C).

The results of magneto-structural analysis of the kimberlite magnetisation carrier minerals are given in (Fig. 8, *c, d*). Almost all the studied samples belong to pseudo-single-domain grains capable of fixing the primary thermal NRM.

The kimberlites of the upper horizons, especially those of the “Detachment”, clearly experienced a temperature impact from the sill of dolerites of the Kuzmovsky complex (third phase) (Fig. 9, *a*; Table 5) – the metachronous mean-temperature component of the NRM vector *B* in the temperature range from 250 to 400 °C agrees with the direction of the primary NRM of the sill (Fig. 9, *d*; Table 5) [17, 44, 45]. Such kimberlites have increased values of *Q* > 1, and, directly, in the endocontact with the dolerite sill æ ≈ 5200·10^{-5} SI, *In* ≈ 2600·10^{-3} A/m, the NRM vector is *Dm* = 229° and *Jm* = -59°. At depth, where the influence of magmatic and exogenous processes decreases, the kimberlites have common factor values of 0.3 < *Q* < =0.4 and gentle inclinations of the *J* vector from -18 to 14° in the first sector of the stereogram. In general, the NRM vectors of kimberlites retained the primary high-temperature component *C*, which corresponds to the Middle Paleozoic tectono-magmatic stage [17, 46, 47].

PPhT-4 (sandstones of the Aikhal Formation C_{2-3}ah), which occur as lenses of low thickness on kimberlites, are practically non-magnetic formations (see Fig. 2, *a*). The density of unaltered sandstones σ = 2160±34.6 kg/m^3 is significantly lower than that of carbonate basement rocks and sandstones orogenised by dolerite sills – σ = 2296±80.2 kg/m^3 (Table 3; Fig. 7). The directions of *in situ* NRM vectors of the latter (PMHs of

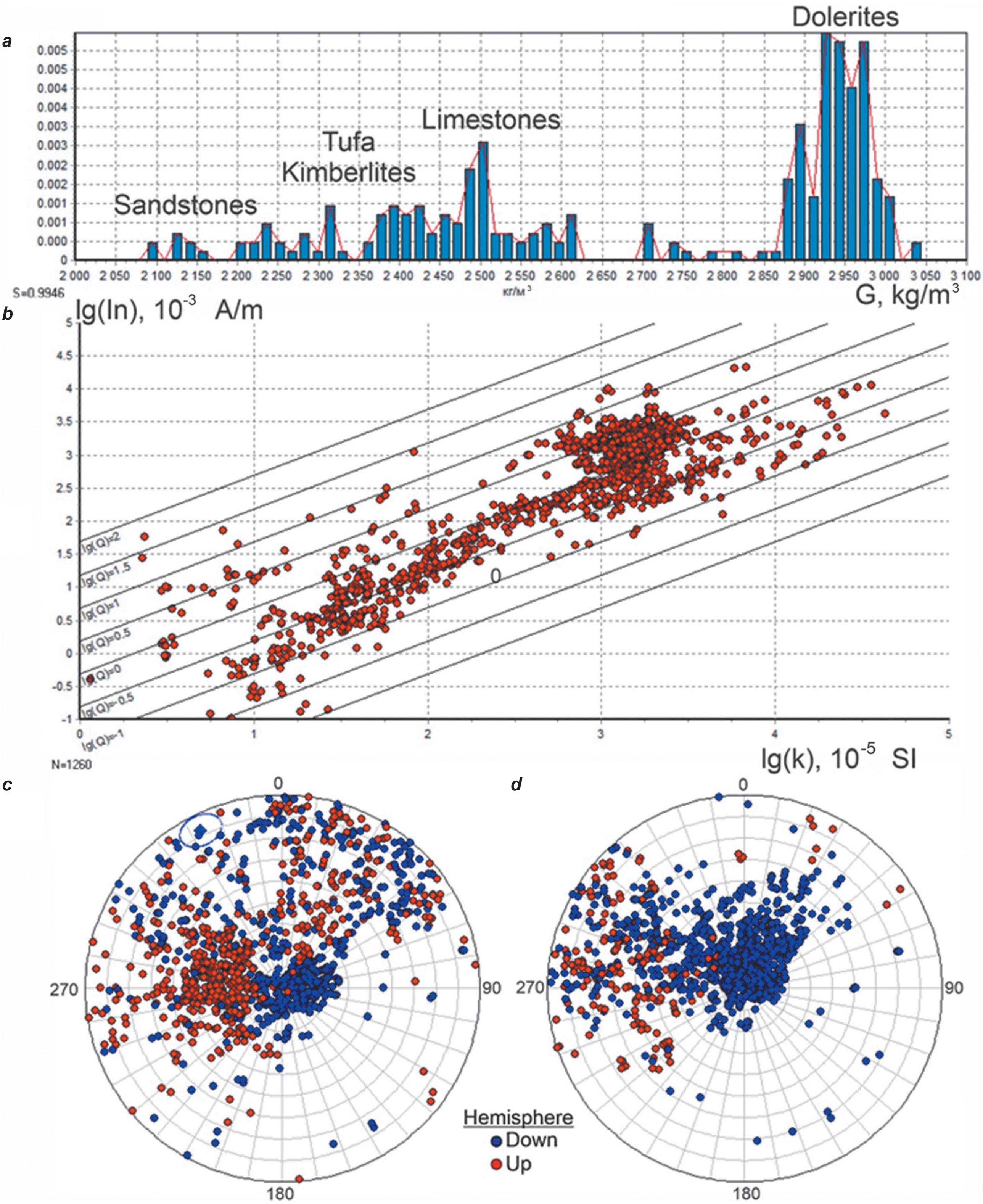

Fig. 7. Distributions of sample physical parameter values from the diamond deposit of the Komsomolskaya kimberlite pipe:
a – histogram of bulk density; b – dependency graph of magnetic susceptibility æ, natural remanent magnetisation In and factor Q; c, d – stereograms of vectors of natural remanent magnetisation In (c) and total magnetisation Is (d)

Рис. 7. Распределения значений физических параметров образцов месторождения алмазов кимберлитовой трубки «Комсомольская»:
а – гистограмма объемной плотности; b – график зависимости магнитной восприимчивости æ, естественной остаточной намагниченности In и фактора Q;
c, d – стереограммы векторов естественной остаточной намагниченности In (c) и суммарной намагниченности Is (d)

Table 3. Spectrum of density and magnetic parameters of the main petrophysical taxa of the diamond deposit of the Komsomolskaya kimberlite pipe *in situ*
Таблица 3. Спектр плотностных и магнитных параметров основных петрофизических таксонов месторождения алмазов кимберлитовой трубки «Комсомольская» в «естественном залегании»

No.	Site (horizon)	*N*	*σ* (s), kg/m^3	*n*	æ (*ε*), 10^{-5} SI	*In*				*Q* (*ε*), units
						In (*ε*), 10^{-3} A/m	*Dm*, °	*Jm*, °	*k* units / α_{95}, °	
Carbonate basement intervening rocks, PPhT-1										
1	26, 28, 29 (280–235)	4	2600 (43)	16	8 (1.06)	0.5 (1.17)	353	18	37.7/6.1	0.13 (1.14)
2	28* (280)	2	2606 (103.7)	10	3 (1.03)	2 (1.21)	61	-20	89.6/5.1	0.98 (1.19)
3	4, 5, 7, 15, 23** (625–610)	6	2352 (133.8)	24	28 (1.38)	6 (1.66)	284	-65	4.2/16.6	0.43 (1.51)
Coherent kimberlites of the Daldyno-Alakitsky intrusive complex ιD_3-C_1dl, PPhT-2 (dyke)										
4	27, 28 (280–235)	16	2321 (59.6)	65	44 (1.17)	6 (1.23)	1	-18	2.9/12.7	0.29 (1.1)
Pyroclastic kimberlite of the Daldyno-Alakitsky intrusive complex ιD_3-C_1dl, PPhT-3 (nec)										
5	9–12 (595)	9	2311 (34.7)	33	828 (1.34)	438 (1.29)	249	50	2.3/21.7	1.09 (1.21)
6	21** (595), kimberlite detachment	–	–	7	5205 (1.13)	2594 (1.26)	229	-59	19.8/13.9	1.02 (1.12)
7	22, 23 (560)	7	2466 (20.8)	55	1673 (1.11)	271 (1.08)	10	8	2.9/13.9	0.33 (1.07)
8	25, 26, 29, 30 (330–235)	43	2509 (15.4)	232	447 (1.13)	92 (1.13)	17	14	2.5/7.5	0.42 (1.04)
Overlying sandstones of Aikhal Formation $C_{2\text{-}3}$ah, PPhT-4 (lens)										
9	3 (632)	3	2160 (34.6)	14	9 (1.06)	15 (1.21)	107	79	81.3/4.4	3.55 (1.22)
10	11** (605)	5	2296 (80.2)	16	73 (1.56)	28 (2.11)	257	-58	12.9/10.7	0.8 (1.55)
Tuffs of Alakit Formation P_2-T_1al, PPhT-5 (lens)										
11	19, 24 (650–625)	6	2425 (129.4)	55	37 (1.04)	7 (1.13)	62	86	24.7/3.9	0.38 (1.13)
12	1, 19** (650–640)	14	2401 (33.2)	54	36 (1.03)	7 (1.14)	284	-62	22.3/4.2	0.42 (1.12)
Dolerites of the Katangsky intrusive complex β_0-$\gamma\beta P_2$-T_1, PPhT-6 (sill)										
13	1–3, 18–20, 24 (650–625)	53	2925 (6.4)	249	1349 (1.03)	1808 (1.04)	77	83	31.1/1.6	2.75 (1.04)
14	5, 15–19** (650–625)	22	2887 (20.7)	119	1288 (1.03)	949 (1.07)	285	-29	1.7/15.7	1.51 (1.07)
Dolerites of the Kuzmovsky intrusive complex $\gamma\beta T_1$, PPhT-7 (sill)										
15	4–7, 10, 13–15, 21–23 (625–550)	52	2962 (4.5)	225	1808 (1.02)	842 (1.05)	284	-51	3.8/5.6	0.96 (1.04)

Note. *N* – is the number of pieces; *σ* – is the arithmetic mean value of bulk density; *s* – is the error of the arithmetic mean; *n* – is the number of cubes; *æ*, *In*, and *Q* – are the geometric mean values of the magnetic susceptibility, natural remanent magnetization, and Königsberger coefficient (In/Ii), respectively; ε – is the error of the geometric mean; *Dm* – mean declination; *Jm* – mean inclination; *k* – accuracy; α_{95} – radius of the 95 % confidence circle of vectors *In*. */** – samples taken in contact with kimberlites/dolerites (petromagnetic heterogeneity of the firing zone [7, 16]).

Table 4. Component chemical composition of magnetisation carrier minerals in the sample kom16-04
Таблица 4. Компонентный химический состав минералов-носителей намагниченности образца kom16-04

Oxide	Probe points									
	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.11	2.12
MgO	5.17	1.17	0.89	9.86	1.65	13.45	0.81	1.98	0.89	7.56
Al_2O_3	–	–	–	0.36	–	0.97	–	–	–	0.23
SiO_2	4.49	1.05	0.72	0.14	1.86	0.13	0.32	1.9	0.67	–
CaO	0.14	0.17	0.16	–	0.16	–	0.08	0.22	0.1	0.08
TiO_2	0.13	0.09	–	51.17	–	54.41	–	–	0.23	46.79
V_2O_5	–	–	–	0.71	–	0.77	–	–	–	0.71
Cr_2O_3	–	–	–	2.06	–	1.77	–	–	–	2.43
MnO	–	–	–	–	–	0,49	–	–	–	–
FeO	80.68	95.42	94.8	39.72	91.19	35.3	90.89	91.15	90.48	42.44
Nb_2O_4	–	–	–	0.37	–	0.3	–	–	–	0.44
Sum	90.61	97.9	96.57	104.39	94.86	107.59	92.1	95.25	92.37	100.68
Mineral	Mgt	Mgt	Mgt	Ilm	Mgt	Ilm	Mgt	Mgt	Mgt	Ilm

Note. The probing points are shown in Figure 8, *a*.

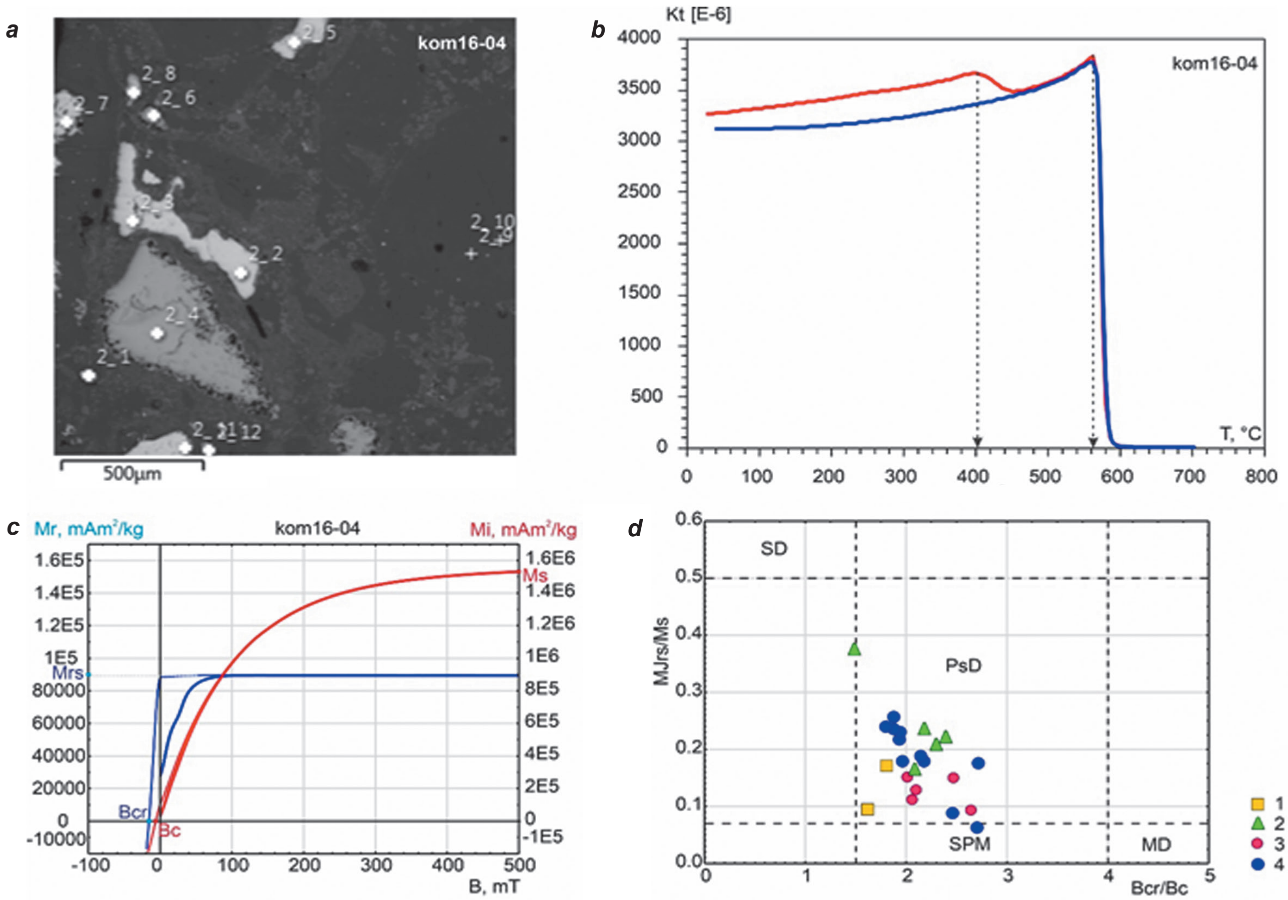

Fig. 8. Magneto-mineralogical studies of the Komsomolskaya pipe kimberlites:
a – backscattered electron micrograph of the sample kom16-04; b – thermomagnetogram of magnetic susceptibility æ (red/blue line – sample heating/cooling process); c – hysteresis loops of induced Mi (red) and residual Mr (blue) saturation magnetisations; d – Day plot: 1 – pyrite vein; 2 – coherent kimberlite; 3, 4 – pyroclastic kimberlites at horizons: 3 – from +595 to +560 m, 4 – from +330 to +235 m (see Table 3)
SD, PSD, MD and SPM – distribution areas of single-, pseudo-, multi-domain and superparamagnetic particles
Рис. 8. Магнито-минералогические исследования кимберлитов трубки «Комсомольская»:
а – микрофотография образца kom16-04 в обратно рассеянных электронах; b – термомагнитограмма магнитной восприимчивости æ (красная/синяя линия – процесс нагрева/охлаждения образца); c – петли гистерезиса индуцированной Mi (красная) и остаточной Mr (синяя) намагниченностей насыщения; d – диаграмма Дея: 1 – пиритовая жила; 2 – когерентный кимберлит; 3, 4 – пирокластические кимберлиты на горизонтах: 3 – от +595 до +560 m, 4 – от +330 до +235 m (см. табл. 3)
SD, PSD, MD и SPM – области распределения одно-, псевдо-, многодоменных и суперпарамагнитных частиц

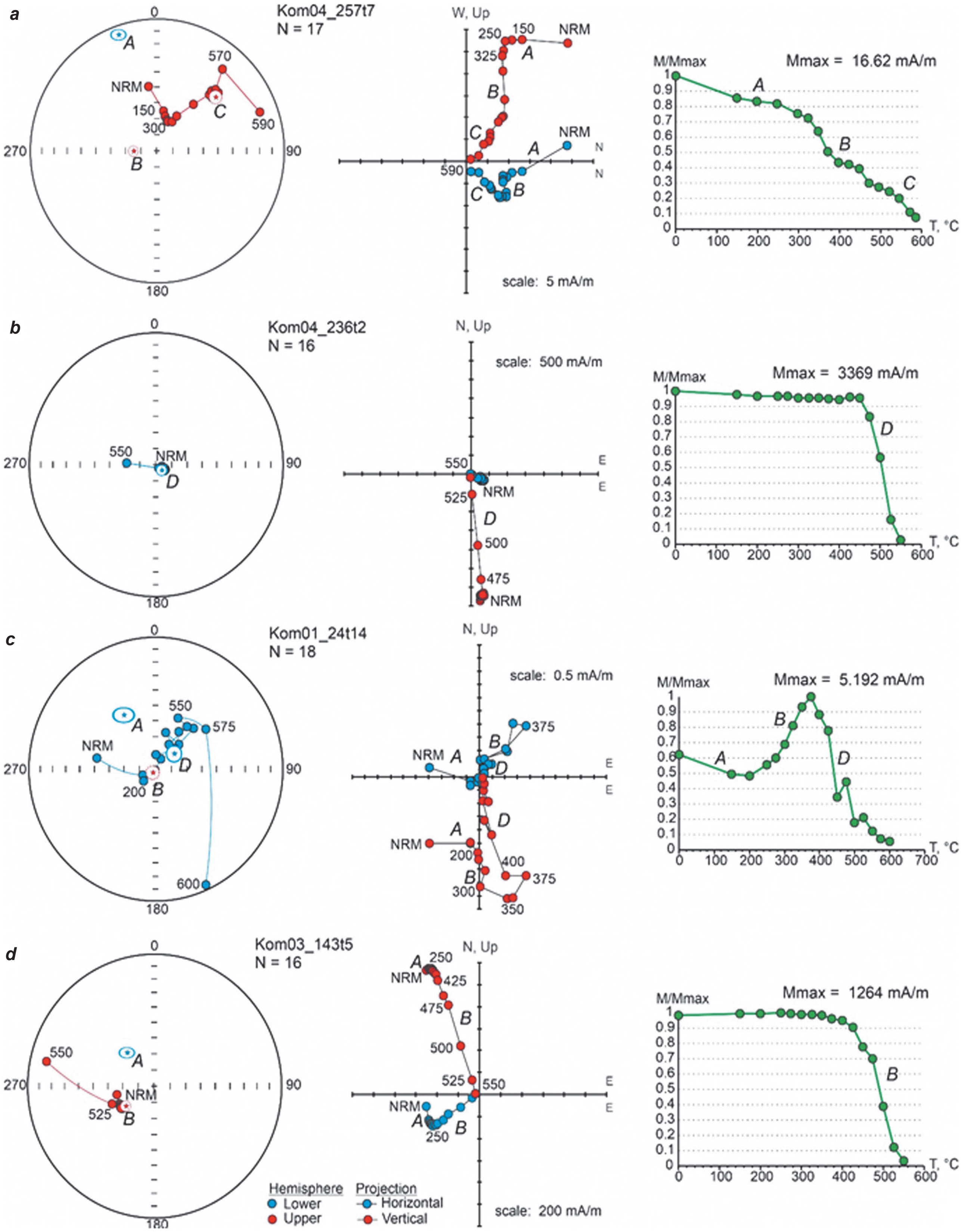

Fig. 9. Paleomagnetic studies of petrophysical taxa of the deposit of the Komsomolskaya kimberlite pipe:
a – kimberlites; b, d – dolerites of the intrusive complexes of Katanga (second phase) and Kuzmovsky (third phase), respectively; c – Alakit Formation tuffs
Рис. 9. Палеомагнитные исследования петрофизических таксонов месторождения кимберлитовой трубки «Комсомольская»:
а – кимберлиты; b, d – долериты катангского (вторая фаза) и кузьмовского (третья фаза) интрузивных комплексов соответственно; c – туфы алакитской свиты

type 2), also agree with the zones of PPhT-1 remagnetisation by sill dolerites of the third phase: *Dm* = 257° and *Jm* = -58°. In general (in terms of size and physical properties), the rocks of this complex are unlikely to significantly distort the anomalous gravimagnetic field of the deposit.

The most serious anomalies-interferences in the observed geophysical fields of the deposit are created by basites of the second and third phases (Fig. 1, *c*, *d*; 5, *a*–*c*) [19]. They are characterised by significant size in volume and varying in a wide range of values of density and magnetic parameters (see Table 3; Fig. 7).

PPhT-5, which includes tuffs of the Alakit Formation P_2-T_1al (Fig. 1, *d*; 4, *d*; 5, *a, d*), is located at horizons from 625 to 650 m and is characterised by average values of density and relatively low values of magnetic parameters (Table 3, Fig. 7; 10) comparable to PPhT-4: σ = 2400 kg/m^3, æ = 37·10^{-5} SI, *In* = 7·10^{-3} A/m, *Q* = 0.38. Tuffs are deposited as lenses of rather significant volumes (length from 50 to 100 m and more, thickness of the first tens of m), which should be taken into account when constructing deterministic PhGM of diamond deposits in the areas of 4 and 5 geotypes. These objects are capable of creating false gravity anomalies on the day surface, similar to kimberlite bodies (pipe-type anomalies). According to NRM vectors in tuffs, two petromagnetic taxa (PPhT) are distinguished: petromagnetic groups (PMG) and PMHs of type 2 [16, 44, 45]. In PMHs of type 2, in contrast to PMG, in addition to the primary component *D*, NRM vectors of metachronous (component *B*) nature (Fig. 9, *c*; Table 5), characteristic of the "firing" zones: *Dm* = 284° and *Jm* = -62°, which indicates their remagnetisation by the sill of the dolerites of the third phase, were established within the temperature range from 150 to 350 °C. In the northern section above the tuffs, characterised by low values of density and magnetisation, there is an increased positive (up to 2 mGal) gravity and intense negative (up to -1000 nT) magnetic anomaly (Fig. 4, *a, b, d*), which is a paradoxical phenomenon in geophysics. Most likely the cause of the observed gravimagnetic anomaly is explained by the deep structure of the deposit. On this basis, it should be interpreted as a structural type SA anomaly, reflecting a favourable prospecting environment on the flanks of the deposit (Fig. 1, *c, d*; 4; 5, *a*).

PPhT-6 (together with PPhT-5) armours the Komsomolskaya deposit at horizons from 625 to 650 m (Fig. 1, *c*, *d*; 2, *a, b*; 4, *d*; 5, *a*–*c*; 12, *a*). Its bulk density reaches $\sigma \approx$ 2900 kg/m^3 and magnetic susceptibility æ ≈ 1300·10^{-5} SI (Table 3, Fig. 7; 10). This fact confirms that the dolerite sill of the second phase is characterised by a

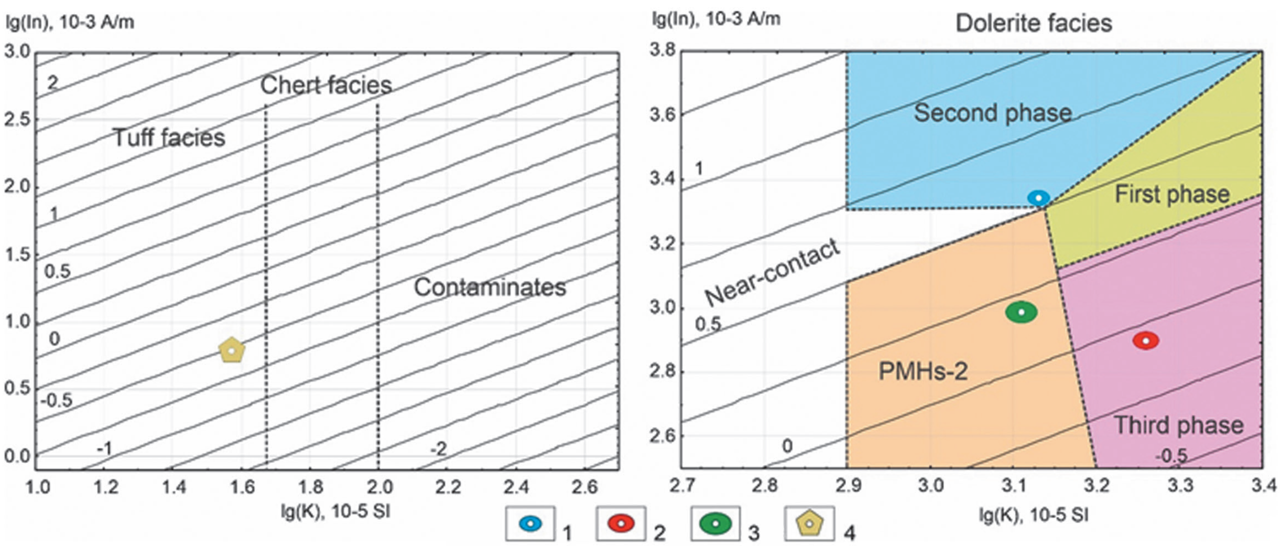

Fig. 10. Facies classification of basite petrophysical taxa of the diamond deposit of the Komsomolskaya kimberlite pipe on the In-æ-Q diagram (according to [44, 45]):
figurative points with 95 % confidence ovals for basites: 1 – PPhT-6a (second phase dolerites); 2 – PPhT-7 (third phase dolerites); 3 – PPhT-6b (firing/stress zone dolerites); 4 – PPhT-5 (Alakit Formation tuffs)

Рис. 10. Фациальная классификации петрофизических таксонов базитов месторождения алмазов кимберлитовой трубки «Комсомольская» на графике In-æ-Q (согласно источникам [44, 45]):
фигуративные точки с овалами доверия 95 % базитов: 1 – PPhT-6a (долериты второй фазы); 2 – PPhT-7 (долериты третьей фазы); 3 – PPhT-6b (долериты зоны обжига/стресса); 4 – PPhT-5 (туфы алакитской свиты)

Table 5. Paleomagnetic characteristics of petrophysical taxons of the Komsomolskaya pipe in comparison with reference data for the Yakutsk diamondiferous province
Таблица 5. Палеомагнитные характеристики петрофизических таксонов трубки «Комсомольская» в сравнении с реперными данными по Якутской алмазоносной провинции

No.	Object [source]	*N*/*n*	*Dm*, °	*Jm*, °	k	α_{95}, °	*Φ*, °	*Λ*, °	*dp*/*dm*, °	*fm*, °
Komsomolskaya diamond deposit (author's data): *φ* = 66° 00'; *λ* = 111° 37'										
1	Third phase of dolerites, In^0 (component *B*)	1/32	259	-75	12.5	7.5	–	–	–	–
2	Second phase of dolerites, In^m (component *B*)	1/41	254	-66	9.3	7.7	–	–	–	–
3	Tuffs of the Alakit Formation, In^m (component *B*)	1/11	245	-68	15.9	11.8	–	–	–	–
4	Tuffs of the Alakit Formation, In^0 (component *D*)	1/17	42	80	10	11.9	–	–	–	–
5	Second phase of dolerites, In^0 (component *D*)	1/57	65	82	25.4	3.8	–	–	–	–
6	Kimberlites, In^m (component *B*)	1/14	302	-75	4.9	20	–	–	–	–
7	Kimberlites, In^0 (component *C*)	1/25	32	-29	14.5	7.9	-5	81	4.8/8.7	17
8	4+5, second phase (component *D*)	2/74	52	81	749	9.1	71	157.5	17/17.6	73
9	1+2+3+6, third phase of dolerites (component *B*)	4/93	262	-72	84.1	10.1	53	175.2	15.7/17.8	57
Published data										
10	Dolerites βPZ_2vm Nyurbinskaya pipe [22]	–	–	–	–	–	-14.6	117.4	3.7/7.1	10
11	Kimberlites ιPZ_2nk Nyurbinskaya pipe [22]	–	–	–	–	–	-11.5	111.2	3.5/7.5	13
12	Basalts D_3ap Frasnian Stage [40]	–	–	–	–	–	1.9	91.7	6.1/9.7	26
13	Dolerites βPZ_2vm Mir pipe [41]	–	–	–	–	–	-0.4	96.6	8.3/13.3	26
14	Kimberlites ιPZ_2dl Verkhnemunskoe deposit [42]	–	–	–	–	–	26.5	142.2	6.2/7.8	46
15	Kimberlites ιMZ_2ol Obnazhennaya pipe [43]	–	–	–	–	–	59.6	143.9	11.1/11.3	75

Note. *N*/*n* – number of sites/samples participating in the statistics. Parameters of grouping vectors of the characteristic NRM: *Dm* – mean declination; *Jm* – mean inclination; *k* – accuracy; α_{95} – is the confidence angle with a probability of 95 % of vectors *In*. Paleomagnetic pole: *Φ* – latitude; *Λ* – longitude; *dp*/*dm* – semi-axes of the oval of 95 % confidence of the paleomagnetic pole; *fm* – paleolatitude.

rather homogeneous chemical and petrographic composition [3]. The geotype of magnetic susceptibility anisotropy (AMS) (see Fig. 6, outcrops 1 and 20) is sedimentary [23]: the magnetic stratification plane is subhorizontal, and the direction of sill movement is south-southwest (Fig. 11, *b*), which indicates their connection with the Vilyuisko-Kotuiskaya fault zone (Fig. 1, *b*). At the same time, PPhT-6 as well as tuffs (PPhT-5) are divided into two types by NRM vectors and *Q* factor. The first PPhT-6a is represented by unaltered dolerites (PMG) and is characterised by $In \approx 1800 \cdot 10^{-3}$ A/m and *Q* = 2.75 and compact vectors *Dm* = 77°, *Jm* = 83°, *k* = 31.1 and α_{95} = 1.6°. Generally, the NRM vectors are magnetically rigid with a *D* component (Fig. 10, *b*; Table 5).

In the second PPhT-6b sill dolerites of the second phase, as well as in PPhT-1, 3, 4 and 5, 30 % of the studied samples (22 pieces) have NRM vectors with $In \approx 950 \cdot 10^{-3}$ A/m and Q = 1.51 with negative polarity Dm = 285°, Jm = -29°, characterised by large scatter k = 1.7 and α_{95} = 15.7° (Table 3, Fig. 7; 10). This is a clear sign of PMHs, the formation of which occurred due to heating and/or pressure from the negatively magnetised sill of dolerites of the Kuzmovsky complex (PMHs-2 and 5 types, respectively, of firing and stress) [6, 7, 16, 47–49]. In addition, in sites 3 and 19, the dyke geotype AMS (the magnetic stratification plane is subvertical, southwestern strike, and in site 5 – sedimentary geotype (Fig. 11, *c*) [5, 23]. The studied PMHs are characterised by rather large sizes (thickness 20 and more m, extension from 100 to 150 m) and wide development in the upper part of the quarry.

The first (PPhT-6a) and second (PPhT-6b) taxa differ markedly in the values of hysteresis parameters (Fig. 12). The second one is characterised by increased values of Mrs and Bcr, which may be determined by the pressure induced from the sill side of the dolerites of the third phase [48, 49]. According to [50], ferromagnetic samples that have experienced stress have an altered domain structure, which can cause a simultaneous change in the AMS geotype. Temperature has little or no effect on the transformation of the original AMS geotype.

At the same time the metachronous NRM *B* component was formed due to the temperature in PPhT-6b (Table 5). In the footwall of the dolerite sill of the second phase, which is in contact with the dolerite sill of the third phase, it completely erased the primary component *D*. With increasing distance (horizon height), the influence of metachronous component *B* weakens and component *D* gradually appears [16, 18]. According to our observations, the thickness of the firing zone can reach from 20 to 25 m (Fig. 1, *d*; 4, *d*; 5, *a*; 11, *a*). Thus, the petromagnetic boundary is shifted upward relative to the petrodense (geological) boundary, which should be taken into account when constructing the PPhM.

PPhT-7 or dolerite sill of the third phase is mainly developed in the carbonate basement at horizons from 550 to 580 m (boundary of the $O_{2\text{-}3}$kl and S_1ln formations), sometimes reaching the horizon 625 m (Fig. 1, *d*; 4, *d*; 5, *a*–*c*; 11, *a*) [10]. The formation of almost all metachronous NRM vectors we have identified in the PPhT of the Komsomolskaya deposit is associated with it. The sill of dolerites of the third phase is characterised by relatively high bulk density σ = 2960 kg/m^3 and, accordingly, magnetic susceptibility $æ \approx 1800 \cdot 10^{-5}$ SI (see Table 3; Fig. 7; 10), which indicates an higher percentage of iron and titanium [3]. On the other hand, dolerites of this phase are characterised by reduced, relative to PPhT-6, values of $In \approx 840 \cdot 10^{-3}$ A/m and Q = 0.96. The *in situ* NRM vectors have mainly negative polarity: Dm = 284°, Jm = -51°, k = 3.8 and α_{95} = 5.6°. According to [16], PPhT-7 basites belong to the PMHs-1 type – bodies remagnetised by the geomagnetic field: the NRM vector includes a viscous low-temperature (up to 250 °C) component *A* and a primary high-temperature component *B* (Fig. 9, *d*; Table 5). There are no metachronous NRM components of geological nature. The dolerite sill of the third phase dolerites also has a sedimentary AMS type, indicating its southwestward movement (Fig. 6; 11, *d*) from the Vilyuisko-Kotuiskaya fault zone (Fig. 1, *b*).

The obtained petrophysical, petro- and paleomagnetic data (Table 3; 5) formed the basis for solving the above tasks on the formation of static (deterministic) PhGM and dynamic PhGM of the diamond deposit of the Komsomolskaya kimberlite pipe, which made it possible to establish a connection between the observed anomalous gravimagnetic field and the structure, material composition, physical characteristics, nature and age of magnetisation of the PhGM in order to substantiate the prospecting physical and geological criteria.

The geological exploration data [10][3] were used to construct a framework for 3D PPhM of the deposit (Fig. 13, *b*). The petrophysical data for the studied PPhT (Table 3) allowed us to calculate the model gravimagnetic fields in the MVP-17.5 programme and compare them with the available geophysical survey data (Fig. 13, *a*). Of particular importance in the construction of a correct PhGM were the PPhTs of types 2 and 5 that we identified in the basites. After removing PPhT basitic bodies from the 3D PPhM (Fig. 13, *c*) using the "exclusion method"[5], their gravimagnetic effect was determined using the

[5] Nikitsky V.E., Glebovskiy Y.S. Magnetic prospecting. Reference book of geophysicist. Moscow: Nedra; 1980, 367 p. (In Russ.) / Магниторазведка. Справочник геофизика / под ред. В.Е. Никитского, Ю.С. Глебовского. М.: Недра, 1980. 367 с.

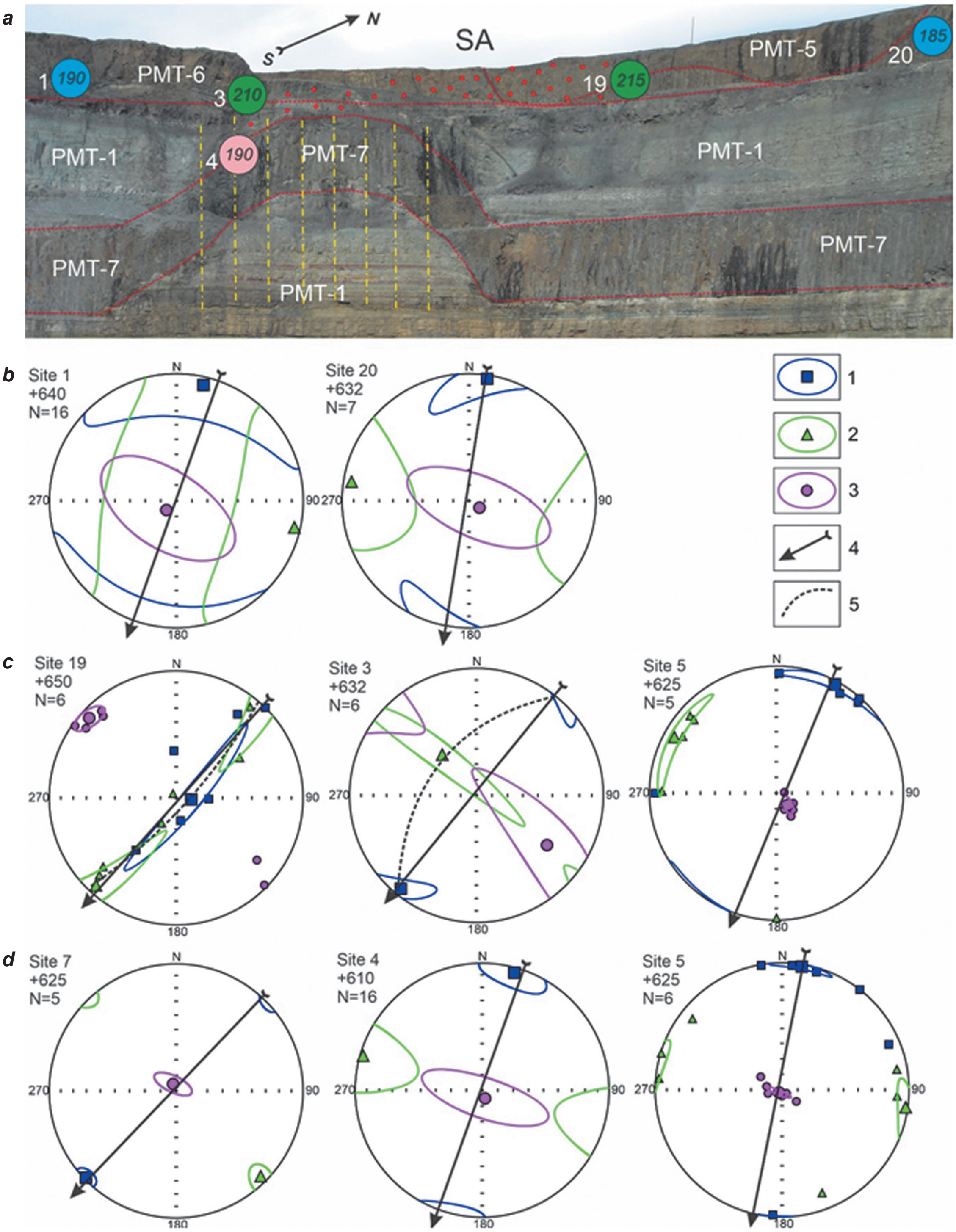

Fig. 11. Study of dolerite magnetic susceptibility anisotropy in the open pit of the diamond deposit of the Komsomolskaya kimberlite pipe:
a – geological section of the north-eastern side of the open pit;
b–d – stereograms of magnetic susceptibility anisotropy
1–3 – ellipsoid axes with 95 % confidence ovals, long K_1, middle K_2 and short K_3, respectively; 4 – direction of dolerite sill movement; 5 – magnetic stratification plane formed by the K_1 and K_2 main axes of the ellipsoid
For other explanations, see Fig. 6

Рис. 11. Изучение анизотропии магнитной восприимчивости долеритов в карьере месторождения алмазов кимберлитовой трубки «Комсомольская»:
а – геологический разрез северо-восточного борта карьера;
b–d – стереограммы анизотропии магнитной восприимчивости
1–3 – оси эллипсоида с овалами доверия 95 %: длинная K_1, средняя K_2 и короткая K_3 соответственно; 4 – направление движения силла долеритов; 5 – плоскость магнитного расслоения, образованная главными осями эллипсоида K_1 и K_2
Другие пояснения см. на рис. 6

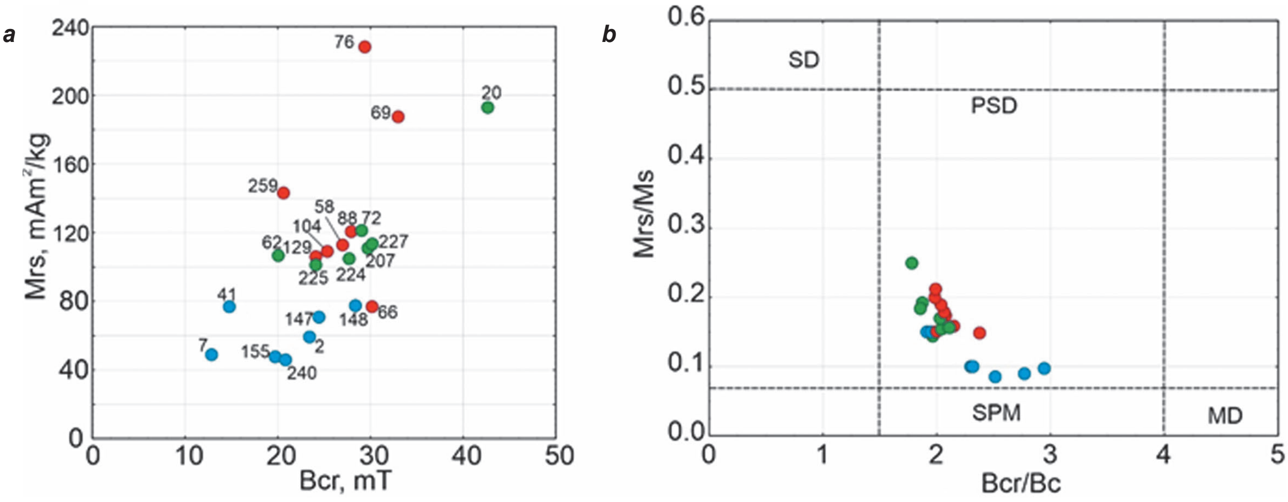

Fig. 12. Magnetostructural analysis of the Komsomolskaya pipe dolerites:
a – dependency diagram of hysteresis parameters of different-phase traps (blue/red/green circles – second phase / third phase / petromagnetic heterogeneities, respectively, numerical symbols – piece numbers); b – Day plot (SPM, SD, PSD and MD – distribution areas of superparamagnetic, single-, pseudo-single- and multi-domain particles, respectively)

Рис. 12. Магнитоструктурный анализ долеритов трубки «Комсомольская»:
а – график зависимости гистерезисных параметров разнофазных траппов (синие/красные/зеленые кружочки – вторая фаза / третья фаза / петромагнитные неоднородности соответственно, цифры – номера штуфов); b – диаграмма Дея (SPM, SD, PSD и MD – области распределения суперпарамагнитных, одно-, псевдоодно- и многодоменных частиц соответственно)

"exclusion method"[5] of their gravimagnetic effect from the total anomalous field, a classical pipe-type anomaly was obtained (Fig. 13, *d*).

The dynamic PhGM of the Komsomolskaya field is based on the obtained palaeomagnetic data on PPhT: kimberlites, basites of the second and third phases of intrusion (Table 5). The calculated poles are compared with previously obtained palaeomagnetic data [27, 40–43] and with the basic apparent polar wander paths (APWP) of the Siberian Platform [51] (Fig. 14, *a*). The virtual geomagnetic pole of kimberlites of the Komsomolskaya pipe (no. 7) agrees quite well with the paleomagnetic poles of kimberlites (no. 11) and basites (no. 10) of the Nyurbinskaya deposits, dolerite dyke of the Mir deposits (no. 13), and basalts of the Appain Formation (no. 14). At the same time, it is noticeably distant from the palaeomagnetic pole of the Verkhnemunskoe diamond deposit (no. 14) [42], the age of which is estimated to be Late Devonian-Early Carboniferous (D_3-C_1, ≈360 Ma). The age of the Komsomolskaya kimberlite pipe may be older (Table 1) [13], which is consistent with the data on the size of its erosion cut [52]. The virtual geomagnetic poles of basites of the second (no. 8) and third (no. 9) phases of intrusion (Table 5; Fig. 14, *a*) correspond to the Early-Middle Mesozoic APWP interval of the Siberian Platform and the palaeomagnetic pole of the Obnazhennaya kimberlite pipe (no. 15).

Palynspastic reconstructions performed under the OPAL-3 programme [39] indicate that the Siberian Platform moved from the equatorial belt of the western hemisphere through the northern polar region during the Phanerozoic, overcoming a path of more than 150° in latitude (Fig. 14, *b*). At the same time, the palaeogeographic reconstructions of the Siberian Platform for the main epochs of kimberlite and trap formation correspond to the position of hot spots [53], which confirms the decisive role of the latter in the manifestation of these tectono-magmatic processes [54]. For example, in the Middle Palaeozoic (376–344 Ma), when the Siberian Platform passed over the hotspots of Madeira, Azores, and Canary Islands, the formation of the Vilyuiskaya Syneclise and associated intrusions of basites and kimberlites occurred [55, 56]. These hot spots left on its surface the Alakit-Kuoisky, Mirninsky, and Okinsky tracks, along which the previously known and newly discovered (Hoptu-Mayskoye and Syuldyukarskoye) kimberlite fields are located (Fig. 14, *c*) [10][1,3]. In the south of the Siberian Platform, according to this dynamic PhGM, the Biryusa-Chunskiy diamondiferous region is predicted to lie to the west of the Mirninsky track. A correction of approximately 22° clockwise angle for the reversal of the Aldan block in post-Middle Paleozoic time is introduced into the northeastern section of the Okinsky track [57].

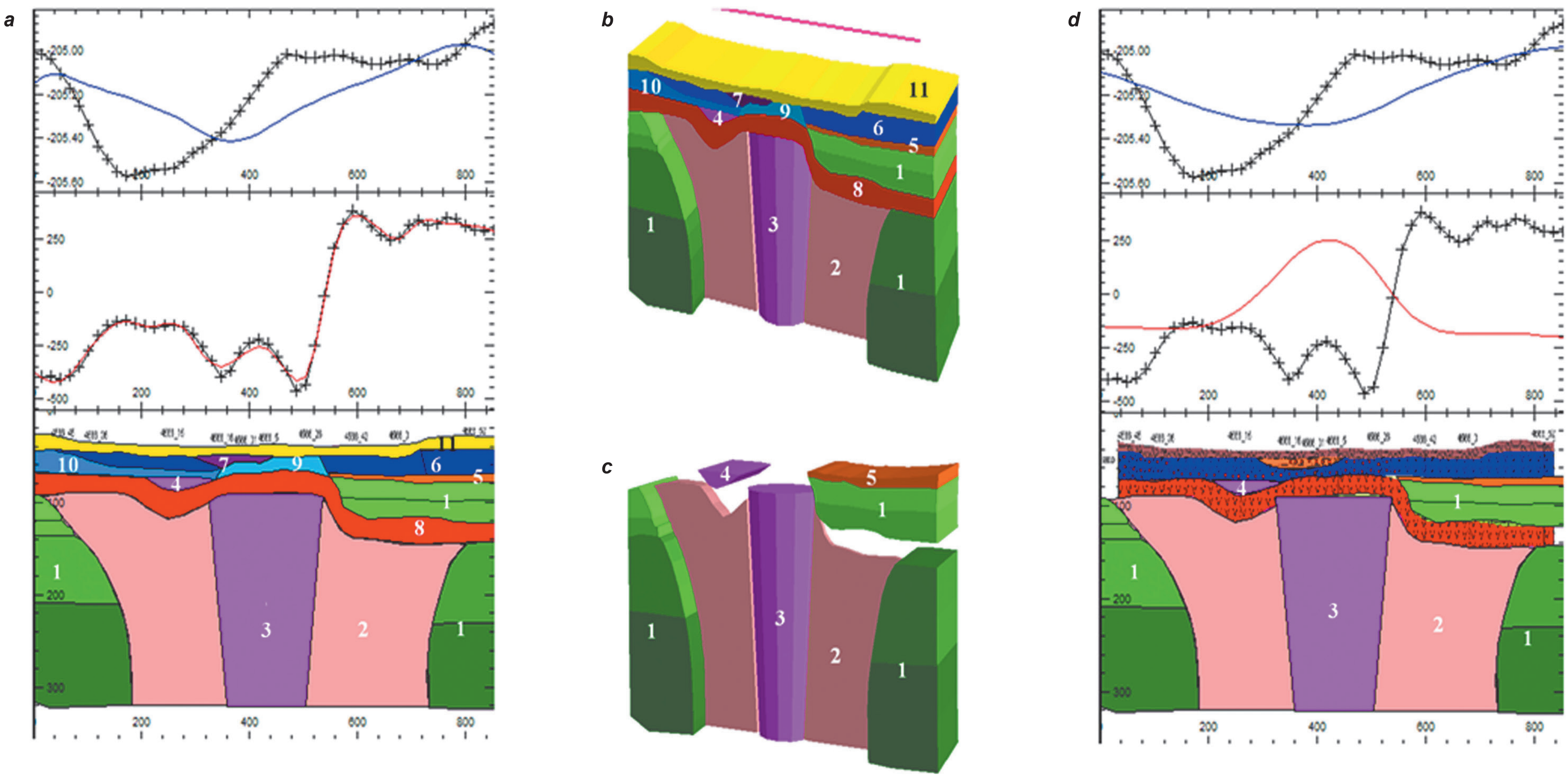

Fig. 13. Solution of the inverse problem of geophysics by "exclusion method" based on a deterministic physical-geological model of the diamond deposit of the Komsomolskaya kimberlite pipe:

a – solution of the direct geophysics problem; b, c – petrophysical model of the sills taking into account basites in the deposit section (b), not taking into account basites in the deposit section (c); d – solution of the inverse geophysics problem by the "exclusion method"[5]

1 – carbonate basement rocks; 2 – coherent kimberlite; 3 – pyroclastic kimberlite; 4 – kimberlite detachment; 5 – Aikhal Formation; 6 – second phase dolerites; 7 – Alakit Formation tuffs; 8 – third phase dolerites; 9 and 10 – petromagnetic heterogeneities of stress (9) and firing (10); 11 – kurums

Рис. 13. Решение обратной задачи геофизики «методом вычитания» на основе детерминированной физико-геологической модели месторождения алмазов кимберлитовой трубки «Комсомольская»:

a – решение прямой задачи геофизики; b, c – петрофизическая модель месторождения с учетом в разрезе базитов (b) и без (c); d – решение обратной задачи геофизики «методом исключения»[5]

1 – породы карбонатного цоколя; 2 – когерентный кимберлит; 3 – пирокластический кимберлит; 4 – кимберлитовый отторженец; 5 – айхальская свита; 6 – долериты второй фазы; 7 – туфы алакитской свиты; 8 – долериты третьей фазы; 9 и 10 – петромагнитные неоднородности стресса (9) и обжига (10), 11 – курумы

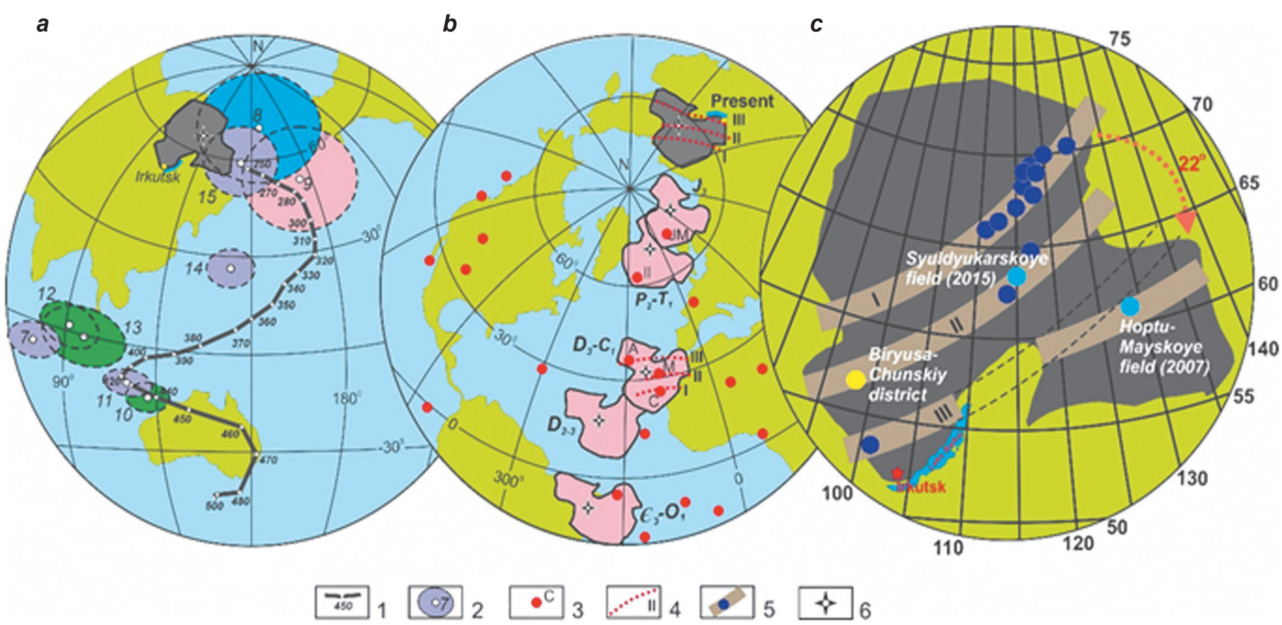

Fig. 14. Dynamic physical and geological model of kimberlite and trap intrusion in the Yakutsk diamondiferous province:
a – paleomagnetic poles (see Table 5); b – paleomagnetic reconstructions of the Siberian Platform in the Phanerozoic; c – position of the Middle Paleozoic kimberlite fields of the Siberian Platform relative to the calculated hotspot tracks
1 – apparent polar wander paths of the Siberian Platform according to [51], figures – geological age million years; 2 – Paleomagnetic poles; 3 – hot spots according to [53]: C – Canary Islands, M – Madeira Islands, A – Azores Islands, Il – Iceland, JM – Jan Mayen; 4 – estimated tracks of hotspots according to [54]: I – Alakit-Kuoisky, II – Myrninsky, III – Okinsky; 5 – hotspot tracks with 95 % confidence intervals (brown stripes) and kimberlite fields (circles): known – blue (old) and blue (new with discovery dates); inferred – yellow; 6 – location of the area under investigation
Рис. 14. Динамическая физико-геологическая модель внедрения кимберлитов и траппов Якутской алмазоносной провинции:
a – палеомагнитные полюсы (см. табл. 5); b – палеомагнитные реконструкции Сибирской платформы в фанерозое; c – положение среднепалеозойских кимберлитовых полей Сибирской платформы относительно рассчитанных треков горячих точек
1 – траектория кажущейся миграции полюса Сибирской платформы по источнику [51], цифры – геологический возраст, млн лет; 2 – палеомагнитные полюсы; 3 – горячие точки по источнику [53]: C – Канарские острова, M – острова Мадейра, A – Азорские острова, Il – Исландия, JM – Джен Майен; 4 – предполагаемые треки горячих точек по источнику [54]: I – Алакит-Куойский, II – Мирнинский, III – Окинский; 5 – треки горячих точек с доверительными интервалами 95 % (коричневые полосы) и кимберлитовые поля (кружочки): известные – синие (старые) и голубые (новые с датами открытия); предполагаемые – желтые; 6 – положение района исследований

The formation of the Tunguskaya syneclise and associated plateau basalts (≈250 Ma) and kimberlites (231–215 Ma) corresponds with the Iceland hot spot [58, 60]. The Jurassic epoch of kimberlite deposition (175–147 Ma) in the north of the Siberian Platform is most likely due to the "work" of the Jen Mayen hot spot.

Conclusion

The works performed in the quarry field of the Komsomolskaya pipe allowed for the first time for YaDP to carry out a comprehensive analysis of the material and structural components in the field structure and to argue for a deterministic PhGM and dynamic PhGM (Fig. 13; 14), which include the following elements:

1. The fault-block tectonics that host the kimberlite pipe determined the behaviour of the third phase of dolerites sill in the carbonate basement. Its transition to the upper horizon was carried out along zones of increased fracturing, due to which such a kimberlite-bearing structure (sigmoid, step) is marked by characteristic gravity ΔG_a and magnetic ΔT_a anomalies (Fig. 1, *d*; 4, *d*; 10, *a*; 11, *a*).

2. In the zone of contact between dolerites of the third phase and host rocks (kimberlites, dolerites and tuffs of the second phase), the latter form PMHs of types 2 and 5, i.e., areas of change in the initial magnetic characteristics due to "firing" and "stress" [6, 7, 16, 18, 44, 45, 48, 49]. Moving in the south-southwest direction (within 185–215°)

from the Vilyuisko-Kotuiskaya fault zone (Fig. 1, *b*; 4, *b*; 6; 11), the negatively magnetised sill of the third phase rose from the lower structural floor of the carbonate basement (horizon 550 m) along the zones of increased fracturing to the bottom of the positively magnetised sill of the second phase (horizon 625 m) (Fig. 1, *d*; 4, *d*; 11, *a*). As a result, the occurrence of reverse polarity NRM vectors in all previously formed PPhTs studied by us is determined by remagnetisation from the sill side of dolerites of the third phase (PPhT-7). Consequently, it is reasonable to consider the firing and stress zones as peculiar PPhTs, the formation of which is associated with a certain geological and tectonic setting. During the formation of type 2 and 5 PMHs in the traps of early intrusion phases, there is a noticeable displacement of petromagnetic boundaries (20 and more m upwards), which should be taken into account in the physical and geological modelling of the upper part of the section [19].

3. The location of the “blind” Komsomolskaya kimberlite pipe is marked by the presence of PMHs of types 2 and 5 in the overlying traps and accompanying elevated gravity ΔG_a and negative magnetic ΔT_a anomalous fields, which are controlled by zones of increased fracturing (Fig. 1, *d*; 4, *a*–*c*; 5, *a*; 11, *a*). It is shown that PMHs are characterised not only by the presence of the metachronous component of the NRM vectors of dolerites of early intrusion phases (first and second), but also dyke type of AMS, increased values of hysteresis parameters, etc. [6, 7, 16, 18, 44, 45, 48, 49]. For this reason, it is logical to consider the PMHs of firing zones in traps of early phases of intrusion as a petrophysical search criterion for the presence of kimberlite pipes in diamond prospecting areas of geotypes 4 and 5 [1] (of course, in combination with geophysical, structural-tectonic, etc. features), and the associated geophysical anomalies as SA of areas promising for the manifestation of kimberlite bodies.

The proposed deterministic PhGM combines the established features of the location and kinematics of the discontinuities with the regularities of changes in the material structure, shape, physical (including magneto-mineralogical and paleomagnetic) properties of the PPhT diamond deposits of the Komsomolskaya pipe and the behaviour of the geophysical fields observed above them within the framework of the functioning of a single tectono-magmatic system as a whole.

Since the geological structure of the Komsomolskaya deposit is not unique (a similar geological situation was also established at the Krasnopresnenskaya pipe [10]), the probability of finding deposits of a similar type in other areas of the eastern side of the Tunguskaya syneclise cannot be ruled out.

4. The NRM vectors, by which the coordinates of the virtual geomagnetic poles of the PPhT are calculated (Table 5; Fig. 14, *a*), are determined by the motion of the Siberian Platform (Fig. 14, *b*). Obviously the age of the Komsomolskaya kimberlite pipe is relatively older compared to a number of YaDP kimberlite pipes [17, 42, 43]. The obtained geomagnetic poles have a sufficiently high statistical representativeness, which is reasonable to use to refine the APWP of the Siberian Platform.

5. The position of the Siberian Platform at the epochs of kimberlite and trap formation agrees well with the currently known hot spots (see Fig. 14, *b*) [53], which may indicate their close parasteric connection [54, 60]. On this basis, it is recommended to develop a regional predictive scheme for the location of kimberlite fields of the Siberian Platform, which will be controlled by hot spot tracks projecting onto its surface. It can be used more widely for forecasting and prospecting of other endogenous deposits in Eastern Siberia.

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Konstantin M. Konstantinov performed sampling, analyzed the materials, made drawings.
Dilyara M. Kuzina performed magneto-mineralogical studies, procesed the materials, made drawings.
Maksim S. Khoroshikh performed sampling, measured magnetic parameters, processed the materials, made drawings.
К.М. Константинов – отбор образцов, анализ материалов, подготовка рисунков, написание текста статьи.
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