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ON THE RHOMBOHEDRAL MODIFICATION IN NATURAL GRAPHITES AND SEMI-GRAPHITES.

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Abstract. The rhombohedral modification existing in natural graphites and semi-graphites obtained from different environments has been measured by using X-ray methods. To avoid the preferred orientation effects in such materials the Debye-Scherrer photographs technique was chosen. The intensities were measured using a Dobson-type microdensitometer and Lirepho photometer. The single crystals have been investigated in precession and Weissenberg cameras.

There are satisfactory relationships between the amount of rhombohedral phase and grain size of specimens and their metamorphic grades. The amount of rhombohedral phase increases from 3 up to 28% with decreasing crystallite size and as the grade of regional metamorphism changes from high to low. It is supposed that the great amount of rhombohedral form in semi-graphites (about 35%) is due to stacking disorder and some influence of turbostratic structure. In monocrystals of pure graphites the amount of rhombohedral phase is negligible.

The present observations are not inconsistent with the view that the metastable rhombohedral structure is produced by mechanical deformation during, or subsequent to the growth of hexagonal graphite.

Graphite has a unique combination of physical, mechanical and chemical properties and so is of interest in a variety of disciplines. Its crystalline properties have been studied extensively, mainly by using X-ray methods, and it is well established that natural graphites can coexist in hexagonal and rhombohedral structural modifications (Lipson and Stokes, 1942; Bacon, 1950; Boehm and Hofmann, 1955; Laves and Baskin, 1956; Nightingale 1962, Walker and Seeley 1958; Hamilton *et al.*, 1970). However, the controversy concerning the occurrence and amount of the rhombohedral form in natural graphites and the mechanism of its formation is not yet resolved. For example, Lipson and Stokes (1942), who were the first to conclude that weak X-ray powder reflections additional to those required for hexagonal graphite were due to the rhombohedral form, found a high concentration of this phase in a sample of Ceylon graphite.

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In single crystal X-ray studies of the same material, Boehm and Hofmann (1955) and Laves and Baskin (1956) found only occasional traces of rhombohedral graphite whereas powder photographs of the same samples gave large amounts. They showed that the rhombohedral modification could be produced by unidirectional pressure associated with some shear or gliding and also that it was thermally unstable, reverting to the hexagonal form on heating to above 2500°C. Freise and Kelly (1963) confirmed these observations using electron diffraction in addition to X-ray methods.

Most investigators have used X-ray diffractometry for powder examination rather than the older photographic methods. The large surface area of specimen and the ease of data processing are advantages for general work, but for a material like graphite that shows pronounced preferred orientation it is difficult to prepare diffractometer specimens free from orientation effects. Of the four techniques commonly used for preparing Debye-Scherrer specimens, Bacon (1952) found that cutting the specimen from a pressed graphite block was the most satisfactory. Filling capillary tubes tends to preserve orientation effects but careful extrusion or rolling methods should allow the amount of preferred orientation to be kept to a minimum.

The aim of the present paper is a reassessment of ideas concerning the existence of the rhombohedral modification in the graphite structure. Investigations were carried out on natural graphites, semi-graphites and graphitized materials obtained from different environment in metamorphic rocks. It was thought that a relationship might exist between the amount of rhombohedral modification and the conditions of formation of natural graphites, for example with their morphological features and with the genetic conditions associated with the host rocks.

In preparing Debye-Scherrer specimens, gum tragacanth was added to the powdered samples and rolled into 0.2–0.5 mm diameter cylinders with the addition of a few drops of water. Visual comparison of photographs of different graphite samples prepared in this way showed good intensity reproducibility for corresponding reflexions having (i) high values of $h^2 + hk + k^2$ and (ii) high values of l^2 .

The specimens were mounted in a Unicam 19 cm and camera α photographs taken with crystal-reflected $\text{CuK}\alpha$ X-radiation from a lithium fluoride monochromator. The photographs appear to show no preferred orientation.

Many previous authors give estimates of the rhombohedral content of natural graphite without giving details of the calculations used. The intensity, I_0 of an X-ray reflection (see for example Cullity, 1956) is given by:

$$I_0 = \frac{KLAp(F_c)^2 Pw}{V_c^2} \quad (1)$$

where:

- K — is a constant,
- L — is a geometrical factor combining Lorentz and polarisation factors and other Θ dependant terms,
- A — is an absorption factor,
- p — is the multiplicity of the reflection used,
- F_c — is the structure amplitude,
- P — is a factor introduced to correct for preferred orientation,

- w — is the weight fraction of the phase concerned,
- V_c — is the unit cell volume.

No absorption correction was applied in the present case because carbon has a very low atomic number (and hence a low absorption coefficient) and also the (100) hexagonal and $(10\frac{2}{3})$ rhombohedral reflections which were used for measurement occur at very similar Θ values and the absorption correction is similar for both.

The possibility of the hexagonal graphite lattice being distorted into an orthorhombic modification has been discussed by some workers (cite reference) but they concluded that any such distortion was too small to be observed. The coordinates of the carbon atoms in the hexagonal unit cell are therefore $\pm(00\frac{1}{4})$, $(\pm\frac{2}{3}\frac{1}{3}\frac{1}{4})$ and in the rhombohedral cell are $\pm(00\frac{1}{3})$, $\pm(\frac{2}{3}\frac{1}{3}0)$ and $\pm(\frac{1}{3}\frac{2}{3}\frac{1}{3})$. In the calculation of F_c , McWeeny's (1951, *vide* Bacon 1959) scattering factors were used and Bacon's (1952) anisotropic temperature factor correction $-0.43(0.23\cos^2\alpha + 0.05\sin^2\alpha)\sin^2\Theta$, where α is the angle between the plane normal and the z-axis, was applied. The unit cell volume enters the calculation to normalise the intensity to a constant number of atoms.

The most thorough correction procedure for preferred orientation is that described by Bacon (1952). He recorded the complete powder ring for particular reflections of high l and high $(h^2 + hk + k^2)$ and then measured the ratio of intensity between the vertical and horizontal position on the ring. On this basis he was able to apply an intensity correction, to each reflection on the photograph depending on the angle between its plane normal and the z-axis. In the present work a negligible intensity difference was observed at different points around the powder rings, and since the angle between the (100) hexagonal and $(10\frac{2}{3})$ rhombohedral plane normals is only 25°, no correction for preferred orientation was applied.

The form of equation (1) used in the present investigation was therefore:

$$I_0 = \frac{KLp(F_c)^2 w}{V_c^2} \quad (2)$$

The terms L , p , $(F_c)^2$ and V_c^2 are constant from film to film and the amounts of rhombohedral and hexagonal phase can therefore be written:

$$W_H = \frac{K_H}{K} I(100) \quad (3)$$

$$W_R = \frac{K_R}{K} I(10\frac{2}{3}) \quad (4)$$

where:

K_H (0.0577) and K_R (0.0168) are the values of $\frac{V_c^2}{Lp(F_c)^2}$ for the two structures. The percentages of rhombohedral and hexagonal phase are then given by $\frac{100 W_R}{W_R + W_H}$ and $\frac{100 W_H}{W_H + W_R}$ respectively.

Although the determination of the amount of rhombohedral modifica-

tion in natural graphites from different sources is difficult because of the complicated and heterogeneous character of graphite-bearing rocks, it is possible to detect some regularities. Since the apparent proportion of the rhombohedral modification in natural graphites depends critically on the previous handling of the material, reproducibility in preparing samples for X-ray examination was emphasized and more precise measurements of the intensities of reflections were made than is apparent in the literature (Hamilton *et al.*, 1970). For example, intensities were measured using a Dobson-type microdensitometer in Newcastle and were subsequently checked on a Zeiss Lirepho photometer in Cracow.

As an example, Figure 1 shows the resolution of $(100)H$ and $(10\frac{2}{3})R$ reflections in several samples with the percentage of rhombohedral phase marked.

The amount of rhombohedral phase in different samples is within the range 3–35%. New data are reported for several different metamorphic grades (Winkler, 1974) of graphite and semi-graphite from localities listed

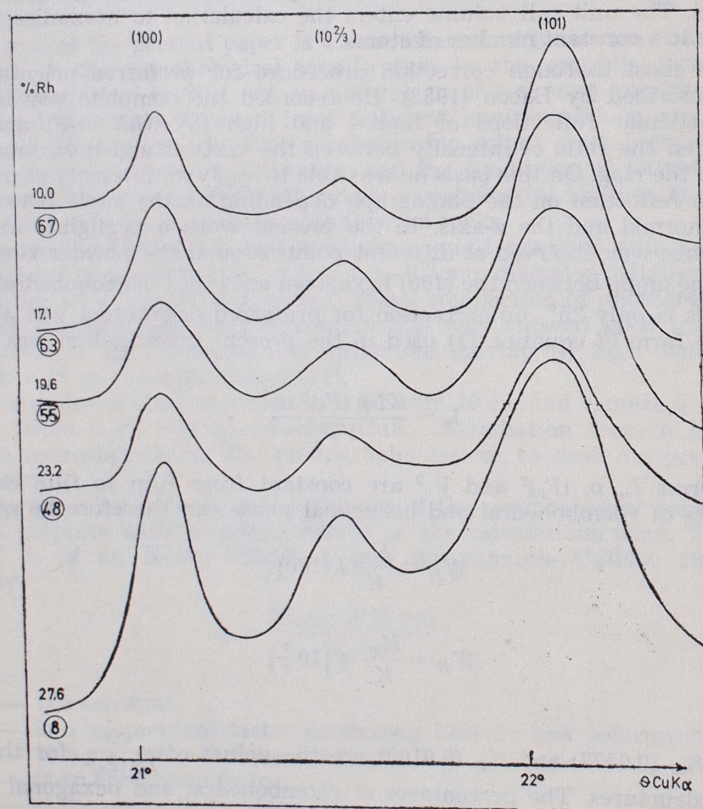


Fig. 1. The resolution of $(100)H$, $(10\frac{2}{3})R$ and $(101)H$ reflections for typical samples. Percentage of rhombohedral phase and sample reference are marked on each curve

in Table 1. They belong to the sequence: low, medium and high grades of regionally metamorphosed rocks shown, according to increasing temperature, in Figure 2 and Table 2. In Figure 2, samples which are formed exclusively from coal seams (i.e. specimens 66, 81, 83) are not included. These particular specimens show semi-amorphous characteristics, and

Table 1

Localities and general characteristics of graphites

Group	% R	Sample references	Locality	General characteristic of graphites and semi-graphites
I	35.0	83	Hurlford, Ayrshire, Scotland	{ semi-graphite formed from coal changed by thermal metamorphism
	35.0	81	Craigman Pit, Ayrshire Scotland	
	32.9	66	Formosa, Asia	semi-amorphous, powdered sample
	27.6	8	Passava, Bavaria, Germany	irregular lenses, powdered sample
	26.6	12	Marcinków, Lower Silesia, Poland	graphitic quartz schist
	25.9	17	Żelowice, Lower Silesia, Poland	graphite ore, powdered sample
	24.8	54	Jaroszów, Lower Silesia, Poland	dispersed in phyllites and quartzites
	23.2	48	Alta valle di Forso, Italy	dispersed in orto-gneiss
	21.0	44	Black Donald mine, Ontario, Canada	grains disseminated in granitic gneiss
	II	25.6	4	Pinerolo, Italy
23.8		16	Witostowice, Lower Silesia, Poland	graphite ore
21.0		10	Sri Lanka (Ceylon)	vein deposit, powdered sample
18.2		6	Male Vrbno, Czechoslovakia	graphite from amphibolites and quartzites
III	23.5	47	Leeds County, Ontario, Canada	irregular impregnations in quartzitic gneiss
	22.1	72	Malinguade, Hill Malawi, Africa	graphite in mica-kyanite gneisses
	19.6	55	Watsche Valley, Rodope, Bulgaria	dispersed in white marble, coarsely crystalline
	17.1	63	Tsavo, Kenya, Africa	graphite gneiss
	10.5	18	Passava, Bavaria, Germany	flinz type disseminated flakes in gneiss
	10.0	67	Lead Hill, Ticonderoga, USA	large flake graphite deposit

Table 1 c.d.

Group	% R	Sample references	Locality	General characteristic of graphites and semi-graphites
IV	7.0	19	Barun Turu, Mongolia	gneisses with garnets and graphite layers
	5.5	7	Madagascar	large flake deposits
	4.2	45	Joly Township Quebec, Canada	vein (lump) deposit
	3.0	61	Sri Lanka, Medapola mine	vein (lump) deposit, large, polycrystalline forms embedded in pyroxene gneiss

Note: Samples 6, 12, 16, 17, 44, 48, 54 were extracted from the rock and chemically purified. Samples 7, 8 and 10 were supplied by Superior Graphite Co., Chicago, Illinois, U.S.A. (Courtesy of: Dr P. R. Carney — Illinois, Dr R. Compagnoni (Italy), Dr C. D. Gribble — Glasgow, Mr D. E. Highley — London, Dr T. Galkiewicz Poland, Dr A. Paulo — Poland, Prof. W. Zabiński — Poland). I wish to thank them for giving the samples to study.

cryptocrystalline or microcrystalline structures. They contain more than 30% of the rhombohedral modification but even small amounts of stacking disorder or of turbostratic structure due to residual coal fragments cannot be neglected and so it is very difficult to establish the precise amount of pure rhombohedral phase.

All the graphite samples are divided in four groups, as shown in Table 3, on the basis of morphological features such as colour, lustre, mode of occurrence, crystal habit and grain size. The first group contains black or blackish-grey graphites and semi-graphites with dull, greasy, pearly or earthy lustre and microcrystalline massive form. In this group there are graphites occurring in a very finely dispersed form in metamorphic rocks or also semi-graphites occurring in seams and lenses which display a coherent, massive texture. Specimens are composed of extremely fine crystals less than 0.01 mm in size and so are only observable under magnification. The percentage of rhombohedral phase reaches about 35%.

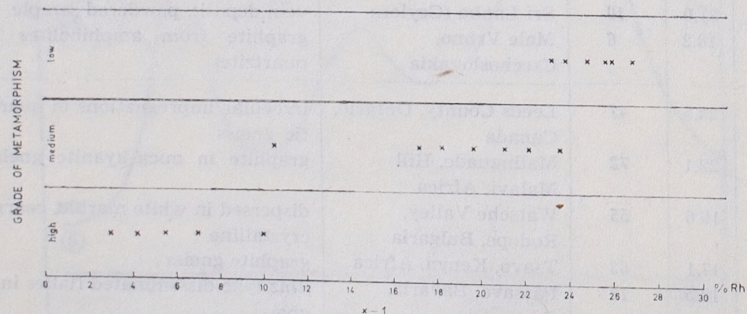


Fig. 2. The relationship between the amount of rhombohedral phase and metamorphic grade (as classified by Winkler, 1974) (x — amount of R phase, as designated in Table 2)

The second group consists of polycrystalline embedded masses with grain sizes 0.01—0.1 mm and show aggregate structures. Their colour is blackish-grey with a silky or semi-metallic lustre. The percentage of rhombohedral phase ranges from about 18 to 26%.

The third group represents graphites with a distinct steel-grey colour and metallic lustre which occur as disseminated flakes with perfect basal cleavage. They are usually tabular foliated crystals of size 0.1—5.0 mm but sometimes they are fibrous, scaly particles with angular or rounded edges. About 10 to 23.5% is estimated in these graphites.

The fourth group includes graphites which occur in large pieces that clearly show a coarse, macrocrystalline structure. Crystal size varies between 5.0 and 50 mm and the amount of rhombohedral phase diminishes to 3%.

The most obvious relationship, as shown by Figure 3, is between grain size and the amount of rhombohedral phase. In the present paper, grain size is defined as the diameter of graphitic particles, flakes or crystal plates occurring *in situ* in deposits or in rocks. Graphites that exist in rocks as very finely dispersed graphitized phytoclasts or in the form of separate nodules, lenses, or seams with semi-crystalline structures contain a greater amount of rhombohedral phase (23.5—35%) than graphites isolated from deposits as individual flakes, plates or macro-single crystals (3—10%). This relationship between grain size and the amount of rhombohedral modification is particularly clear in the case of specimens 8 and 18 (samples from the Passava deposit) and 10, 61 (samples from Sri Lanka deposit). Specimens 18 and 61 are taken originally from deposits but 8 and 10 are powdered samples, supplied by Superior Graphite Co. Chicago, Illinois. Even so, it is worth remembering that most graphite crystals are distorted due to movements in the embedding rock.

Also, it can be supposed that many rocks have been sheared at some time, as noted by previous workers (Lipson and Stokes, 1942; Laves and Baskin, 1956; Boehm and Hofmann, 1955; Freise and Kelly, 1963; Hamilton *et al.* 1970).

The formation of the rhombohedral phase in natural graphites might therefore be explained by mechanical deformation which gives rise to the selective and joint gliding of pairs of planes.

Table 2

The relationship between the grade of metamorphism and percentage of rhombohedral phase (% Rh)

Metamorphic grade	Sample references	% Rh
Low	12	26.6
	17	25.9
	4	25.6
	54	24.8
	16	23.8
Medium	48	23.2
	47	23.5
	72	22.1
	44	21.0
	55	19.6
	6	18.2
High	63	17.1
	18	10.5
	67	10.0
	19	7.0
	7	5.5
	45	4.2
	61	3.0

Table 3

Morphological features, grain size and amount of rhombohedral phase in natural graphites

Group	Colour	Lustre	Mode of occurrence	Crystal habit	Grain size mm	%R
I	black or blackish-grey	dull, greasy, pearly or earthy	grains and particles finely dispersed or embedded	crypto- and micro-crystalline or massive forms	0.001—0.01	35.0—21.0
II	blackish-grey or steel-grey	silky or semi-metallic	poly-crystalline aggregates, compact concentrations	micro-crystalline	0.01—0.1	25.6—18.2
III	steel-grey	metallic	disseminated flakes with perfect basal cleavage	fibrous, scaly particles with angular or rounded edges	0.1—5.0	23.5—10.0
IV	steel-grey silvery or lead-grey	metallic, very strong	large lumps individual crystals	macro-crystalline or coarsely crystalline pieces	5.0—50.0	7.0—3.0

Amelinckx (1964) described the process of *synchro-shear* for graphite in which the structure is changed from hexagonal to rhombohedral by a martensite-type transformation: "The change in lattice symmetry is produced by restacking the carbon atoms, distorting the bonds and inserting stacking faults and other defects".

The continuous decrease in the amount of rhombohedral phase with increase in the grain size of the particles has been confirmed by Kwiecińska and Kajzar (1975) using neutron diffraction methods.

The very small amount of rhombohedral phase in the Sri Lanka vein deposit specimens (Fig. 3) suggested a determination of its general occurrence in graphite monocrystals. Single crystals for this purpose were obtained from Ticonderoga, Sri Lanka, Passava, Kenya and Bulgaria deposits. These crystals have been investigated in precession and Weissen-

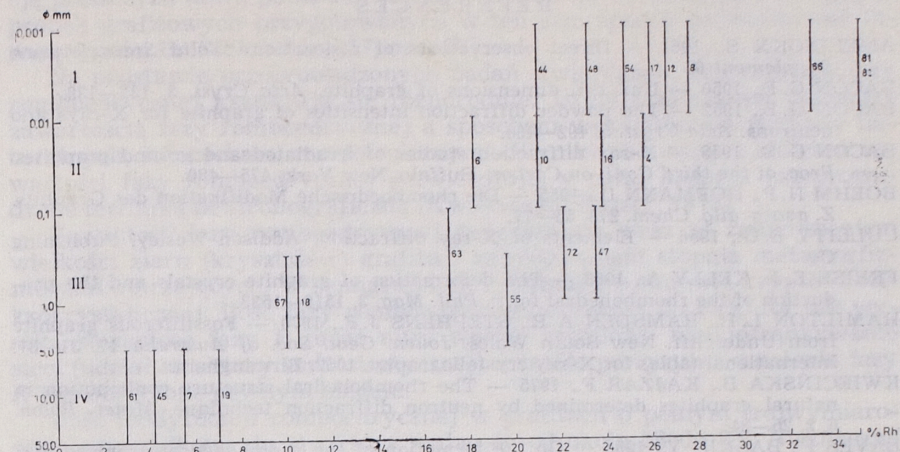


Fig. 3. The relationship between the amount of rhombohedral phase and grain size of graphites

Specimen numbers are the same as in Table 1

berg cameras mounted about the a and c axes. Exposures were made over different regions of the crystals but no reflections ($10\frac{2}{3}$) and ($10\frac{4}{3}$) were ever observed. It can be concluded that the amounts of rhombohedral phase in these single crystals are negligible.

CONCLUSIONS

The amount of the rhombohedral structural modification in natural graphites increases with decreasing crystallite size and as the grade of metamorphism decreases from high to very low. In graphite monocrystals, irrespective of origin, the amount of rhombohedral form is negligible whereas in microcrystalline or cryptocrystalline graphites it can reach about 28%. In semi-graphites was found even 35% but due to stacking disorder and some disturbance of turbostratic structure it is very difficult to establish the precise amount of pure rhombohedral phase. The observations are not inconsistent with the view that the rhombohedral structure is thermally unstable and is produced only by mechanical deformation during, or subsequent to, the growth of hexagonal graphite.

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MODYFIKACJA ROMBOEDRYCZNA W GRAFITACH I SEMIGRAFITACH NATURALNYCH

Streszczenie

W pracy przedstawiono wyniki badań rentgenostrukturalnych próbek pochodzących ze złóż grafitów i semigrafitów naturalnych, oraz substancji zgrafityzowanych, rozproszonych w skałach występujących w różnych fałdach metamorfizmu regionalnego i kontaktowego.

Głównym problemem podjętym w tej pracy jest reinterpretacja dotychczasowych koncepcji dotyczących obecności modyfikacji romboedrycznej w strukturze grafitu. Badania wykonano metodą Debye-Scherrer-Hull'a z rejestracją filmową stosując promieniowanie $\text{CuK}\alpha$ monochromatyzowane LiF . Do określenia ilościowego udziału fazy romboedrycznej wybrano linie (100) i (101) — heksagonalne oraz $(10\frac{2}{3})$ — romboedryczną. Intensywność linii mierzono za pomocą mikrofotometru Dobson'a. W obliczeniach zawartości fazy romboedrycznej uwzględniono czynniki strukturalny, polaryzacyjny Lorentz'a i temperaturowy, pominięto natomiast czynniki absorpcji z uwagi na bardzo zbliżone wartości kątów Θ dla płaszczyzn (100) i $(10\frac{2}{3})$. Nie uwzględniono również czynnika odpowiedzialnego za orienta-

cję płaszczyzn (hkl), ponieważ zaobserwowano na debyeogramach różnych próbek grafitowych przygotowanych w ten sam sposób powtarzalność intensywności linii ($h^2 + hk + k^2$) oraz l^2 .

Na podstawie przeprowadzonych badań stwierdzono, że zawartość fazy romboedrycznej kształtuje się różnorodnie. Istnieją zależności pomiędzy zawartością fazy romboedrycznej a sposobem wykształcenia grafitów naturalnych, ich cechami morfologicznymi. Wyniki pomiarów i obliczeń zawartości fazy romboedrycznej potwierdzają w pełni badania przeprowadzone techniką neutronograficzną (Kwiecińska, Kajzar, 1975).

Zawartość fazy romboedrycznej zwiększa się wraz ze zmniejszeniem wielkości ziarn (kryształów) grafitu i zmniejszeniem stopnia metamorfizmu skał otaczających. W semigrafitach i grafitach o budowie krypto- i mikrokrystalicznej, ilość fazy romboedrycznej dochodzi do 35%. Na tak wysoką zawartość fazy R może mieć wpływ częściowe nieuporządkowanie sieci (udział struktury turbostratycznej) a zatem precyzyjne ustalenie fazy R jest obarczone pewnym błędem.

Ilość modyfikacji romboedrycznej w grafitach o pełnym trójwymiarowym uporządkowaniu struktury waha się od około 28 do 3%. Nieznaczna zawartość fazy R stwierdzona w dużych makrokryształach grafitów naturalnych skłoniła autorkę do poszerzenia badań rentgenowskich o pomiary monokryształów w kamerach: precesyjnej i Weissenberg'a. W monokryształach pochodzących ze złóż Sri Lanka, Ticonderoga, Passava, Bulgaria i Kenia, orientowanych wzdłuż osi a i c, naświetlanych w różnych kolejnych punktach powierzchni nie zarejestrowano refleksów $(10\frac{2}{3})$ ani też $(10\frac{4}{3})$. Wniosek wynikający z tych badań jest jednoznaczny: obecność fazy romboedrycznej w monokryształach grafitu, niezależnie od ich pochodzenia jest znikoma.

Wykonane badania nie zaprzeczają poglądom, że faza romboedryczna jest termicznie niestabilna oraz że powstaje przez mechaniczną deformację sieci następującą w czasie wzrostu podstawowej struktury heksagonalnej.

OBJAŚNIENIE FIGUR

- Fig. 1. Rozdzielenie refleksów $(100)H$, $(10\frac{2}{3})R$ i $(101)H$ przedstawione dla kilku charakterystycznych próbek
Procentowa zawartość fazy romboedrycznej i numery próbek są zaznaczone na każdej krzywej
- Figi. 2. Zależność pomiędzy zawartością fazy romboedrycznej a stopniem metamorfizmu (według klasyfikacji Winklera, 1974)
(x — zawartość fazy romboedrycznej, jak w tabeli 2)
- Fig. 3. Zależność pomiędzy zawartością fazy romboedrycznej a wielkością kryształów grafitu
Numery próbek są te same co w tabeli 1

РОМБОЭДРИЧЕСКАЯ МОДИФИКАЦИЯ В ПРИРОДНЫХ ГРАФИТАХ И СЕМИГРАФИТАХ

Резюме

В работе представлены результаты рентгеноструктурных исследований образцов отобранных из месторождений природных графитов и семиграфитов, рассредоточенных в породах из разных фаций регионального и контактного метаморфизма.

Основной проблемой, которая изучалась в этой работе, была реинтерпретация существующих концепций, касающихся присутствия ромбоэдрической модификации в структуре графита. Исследования велись по методу Дебие-Шеррер-Галла с применением फिल्मовой регистрации и CuK_α радиации (монохроматор LiF). Для определения количественного участия ромбоэдрической фазы были избраны линии (100) и (101) — гексагональные и $(10\frac{2}{3})$ — ромбоэдрическая. Интенсивность линий измерялась при помощи микрофотометра Добсона. При расчётах содержания ромбоэдрической фазы учитывались структурный, поляризационный Лоренца и температурный факторы; в то же время не учитывался фактор абсорбции в связи с тем, что величины углов Θ для плоскостей (100) и $(10\frac{2}{3})$ очень близки. Не учитывался тоже фактор ответственный по ориентировке плоскостей (hkl), так как наблюдалась на одинаково приготовленных дебиограммах разных образцов графита повторяемость интенсивности линий $(h^2 + hk + k^2)$ и l^2 .

На основе проведённых исследований можно констатировать, что содержание ромбоэдрической фазы очень разнообразно. Существуют зависимости между содержанием ромбоэдрической фазы и формой природных графитов, их морфологическими характеристиками. Результаты расчётов и измерений содержания ромбоэдрической фазы подтверждают в целом исследования проведённые при помощи нейтроннографической техники (Квещинска, Кайзар, 1975).

Содержание ромбоэдрической фазы возрастает по мере уменьшения величины зёрн (кристаллов) графита и с уменьшением степени метаморфизма окружающих пород. В семиграфитах и графитах с крипто- и микрокристаллическим строением количество ромбоэдрической фазы достигает 35%. На столь большое количество фазы R может влиять частичная неупорядоченность решётки (участие турбостратической структуры), в связи с чем точное определение фазы R всегда связано с некоторой ошибкой.

Количество ромбоэдрической модификации в графитах с полной трёхмерной упорядоченностью структуры колеблется от около 28 до 3%. Незначительное содержание фазы R, которое было отождествлено в больших макрокристаллах природных графитов, привело автора к расширению рентгеновских исследований. Монокристаллы изучались в прецессионной камере и в камере Вейссенберга. В монокристаллах из месторождений в Сри Ланка (Цейлон), Тикондерога, Пассава, Болгария и Кения, ориентированных вдоль осей a и c, освещаемых в разных очередных точках поверхностей, не наблюдались рефлексы $(10\frac{2}{3})$ и $(10\frac{3}{4})$.

Вывод сделанный на основе этих исследований — однозначный: присутствие ромбоэдрической фазы в монокристаллах графита, независимо от их происхождения, очень незначительное.

Проведённые исследования не противоречат мнениям, что ромбоэдрическая фаза термически нестабильна, и что возникает она из-за механической деформации решётки, которая происходит во время возрастания основной гексагональной структуры.

ОБЪЯСНЕНИЯ К ФИГУРАМ

- Фиг. 1. Распределение рефлексов $(100)H$ $(10\frac{2}{3})R$ и $(101)H$ показанное для нескольких характеристических образцов
Процентное содержание ромбоэдрической фазы и номера образцов обозначены на каждой кривой
- Фиг. 2. Зависимость между содержанием ромбоэдрической фазы а степенью метаморфизма (по классификации Винклера, 1974)
x — содержание ромбоэдрической фазы то же самы, что в таблице 2
- Фиг. 3. Зависимость между содержанием ромбоэдрической фазы а величиной кристаллов графита
Номера образцов то же самы, что в таблице 1