Quantitative characteristic of graphite in marbles from Central and East Rhodopes

Количествена характеристика на графита в мраморите от Централни и Източни Родопи

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Graphite-bearing dolomite-calcite marbles from the Rhodopes (Byalata Skala quarry, Madan ore field, Ardino–Nedelino line and SW of Chernichevo village) were studied. The quantity of graphite in marbles varies from 0.01 to 1.67 wt.%, most often between 0.20–0.60, and rarely up to 0.80 wt.%. The highest average graphite contents were established in marbles from the Byalata Skala quarry – 0.72 wt.% (Stoykov et al., 1986; Brankin et al., 1988; Trashliev, 1989; Vlahov, 1991, 2005, 2006, 2007), but these contents are too low to be of commercial interest.

It was noticed in previous studies that visually estimated graphite contents in marbles are always vastly higher than the weight contents measured in licensed laboratories. The visual estimation of graphite contents includes: optical contents (percentage of the mineral within a thin section), areal contents (surface area of graphite grains, relative to the total surface area of a sample) and linear contents (intercepts of graphite along a series of lines). The weight and optical contents (%) of graphite are both established in licensed labs during geological explorations and studies. These data are available in the above cited publications of the author. The areal contents represent new macroscopic estimates based on cube-shaped samples of marbles. The areal contents of graphite were measured (mm^2) on cube faces and average areal percentages were also calculated. The quantities of silicate, ore and other minerals are insignificant that allows estimation of graphite and carbonates contents (mm) along 8 directions on all visible surfaces in each sample or photos available. The results were calculated in linear percentages as follows: linear %, calculated on the basal surfaces or sections of graphite flakes, mainly on schistosity surfaces; linear %, calculated on the prismatic surfaces or sections of graphite, most often across schistosity, and linear % of whole samples, calculated as an average from linear % of basal and prismatic surfaces.

The established correlation between average weight and average optical, areal and linear contents of graphite is shown in Table 1.

The values of optical, areal and linear quantities are always significantly higher than corresponding weight contents of graphite in marbles. The large differences between visually estimated or measured contents and weight percentage of graphite in mar-

Table 1. Correlation between visual and weight contents (%) of graphite in marbles from the Rhodopes

Visual determination of graphite contents	Number of samples	Visual quantities of graphite (%)	Variation (weight %)	Average (weight %)	Ratio (average visual %/ average weight %)
Optical content	7	<1.00	0.09–0.79	0.32	n. d.
Optical content	30	1.00–5.00	0.18–1.61	0.66–0.73	1.52–6.85
Macroscopic average areal content	7	1.08–2.35	0.24–0.83	0.22–0.82	2.42–4.25
Macroscopic average linear content of whole samples	9	2.44–6.57	0.21–0.83	0.22–0.82	8.01–11.09

Table 2. Quantitative estimation of graphite contents in marbles using equations 1–5

Weight % of graphite	Calculated approximate optical % of graphite	Calculated approximate areal % of graphite	Calculated approximate linear % on the basal surfaces of graphite	Calculated approximate linear % on the prismatic surfaces of graphite	Calculated approximate linear % of whole samples
0.10	<<1.00	0.20–0.40	0.70–1.40	0.60–0.90	0.80–1.10
0.20	<1.00	0.50–0.90	1.50–2.80	1.30–1.80	1.60–2.20
0.30	<1.00	0.70–1.30	2.30–4.20	1.90–2.70	2.40–3.30
0.40	<1.00	1.00–1.70	3.00–5.60	2.60–3.60	3.20–4.40
0.50	≈1.00	1.20–2.10	3.80–7.00	3.20–4.60	4.00–5.60
0.60	≈1.00	1.50–2.60	4.60–8.40	3.80–5.50	4.80–6.70
0.70	>1.00	1.70–3.00	5.30–9.80	4.50–6.40	5.60–7.80
0.80	>1.00	2.00–3.40	6.10–11.20	5.10–7.30	6.40–8.90
0.90	>1.00	2.20–3.80	6.90–12.60	5.80–8.20	7.20–10.00
1.00	1.50–7.00	2.40–4.30	7.60–14.00	6.40–9.10	8.00–11.10
2.00	3.00–14.00	4.90–8.50	15.30–27.20	12.80–18.20	16.00–22.20
3.00	5.00–21.00	7.30–12.80	22.90–41.00	19.20–27.30	24.00–33.30
4.00	6.00–28.00	9.70–17.00	30.50–54.50	25.60–36.30	32.00–44.40
5.00	8.00–35.00	12.10–21.30	38.10–68.00	32.00–45.40	40.00–55.50
6.00	9.00–41.00	14.60–25.50	45.70–81.70	33.40–54.50	48.06–66.54
7.00	11.00–48.00	17.00–29.80	53.40–95.30	44.80–63.60	56.00–77.60
8.00	12.00–55.00	19.40–34.00	>61.00	51.20–72.70	64.0–88.70

bles are due to: 1) the flake habit of graphite crystals, situated among well-developed three-dimensional carbonate grains; 2) the calculated density of graphite is 2.25 g/cm^3, but as a rule, its real measured density is lower (2.09–2.23 g/cm^3), and the density of calcite is 2.71 g/cm^3; 3) graphite flakes are situated in gray parts of marbles with higher contents of dolomite, whose density is even higher (2.84 g/cm^3); 4) very small quantities of graphite are easily visible, because of the high contrast in colours of carbonate minerals and graphite (Vlahov, 2007).

It was established that a stable correlation, with small dispersion of values, exists between the linear, areal and weight percentages. The inconformity between linear and weight percentages decreases with increasing of the real quantity of graphite in marbles. All these correlations can be expressed by some simple equations (1–5) where G is graphite:

$G_{(opt.\%)} = G_{(wt.\%)} \times (1.5–7.0)$ (1)

$G_{(areal\%)} = G_{(wt.\%)} \times (2.4–4.3)$ (2)

$G_{(lin.\ basal\%)} = G_{(wt.\%)} \times (7.6–14.0)$ (3)

$G_{(lin.\ prism.\%)} = G_{(wt.\%)} \times (6.4–9.1)$ (4)

$G_{(lin.\ sample\%)} = G_{(wt.\%)} \times (8.00–11.1)$ (5).

These equations can be used for an approximate but very fast quantitative estimation of graphite contents in marbles (Table 2). Contents over 1.67 wt.% have not been detected yet in the Bulgarian parts of the Rhodopes, but since such values are economically significant, they are extrapolated presuming that obey the same correlations.

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