# Measuring the color of granite rocks. A proposed procedure

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**Abstract:** In spite of color is one of the physicochemical parameters most commonly used to characterize ornamental stone, there is as yet no standardized protocol for measuring this parameter. Such a protocol is of particular importance for characterizing the color of heterogeneous surfaces, as in the case of granite. The aim of the present study was to determine the minimum area and number of measurements required to characterize the color of granite rocks. A spectrophotometer and a tristimulus colorimeter, showing a minor variation inter-instrumental, were used to measure the color of granite samples, and the measurements were expressed in CIEL*a*b* color system units. Three parameters were considered as variable factors: the type of rock (*Labrador Claro, Grissal; Rosa Porriño* and *Blanco Cristal*), surface finish (polished, honed, sawn and flamed) and target area (circular apertures of diameter 5, 8, 10 and 50 mm). The results of the application of MANOVA and of the classical CIEL*a*b* formula and CIEL*a*b*-based color-difference formulae (i.e. CIE94 and CIEDE2000) to the data revealed that, although all considered factors affected the minimal area and number of measurements required, the different circular apertures of both instruments can be disregarded if the number of measurements and area recommended in this work are used.

**Keywords:** color measurement, granitic rocks, minimum area of measurement, minimum number of measurements, CIEL*a*b*.

## Introduction

Although color is frequently determined in studies involving the conservation and restoration of historical stone artworks, no standardized protocol for measuring color has yet been established for ornamental stones. Such a protocol is particularly necessary for measuring the color of stones constituted by minerals of very different colors, such as granite rocks. The measuring instruments used at present -colorimeters, spectrophotometers and telespectroradiometers- have some limitations in terms of measuring the color of heterogeneous surfaces, because the required integration of the field of view may produce an unrealistic color.[1] Furthermore, in the case of colorimeters and spectrophotometers, the target area is always circular and of a size determined by the diameter of the measurement head (<60 mm), and therefore color measurements must be made sequentially, i.e. point-by-point, and the representative color of the whole non-homogeneous surface cannot be determined by a single measurement.

Prior determination of the number of measurements must therefore be made because of these limitations, so that the results be reproducible and the results of diverse types of studies can be compared, such as those involving measurement of the color of granite rock in order to characterize the material;[2,3] color changes produced by consolidation and/or hydrofugation treatments;[4,5,6] the ageing and weathering effects caused by environmental agents,[3,7,8] and the change in color produced by biological colonization.[9]

Moreover, although the International Commission on Illumination (*Commission International de L'Eclairage*: CIE)[10] has explicitly recommended study of the color of surfaces of different texture, so far relatively few studies have focused on the methodology of study.[11,12] In some studies the color changes produced by different mechanical surface treatments applied to ornamental rocks have been quantified and the importance of these types of measurements stressed.[3] However, as there is no standardized protocol, aspects such as the number of measurements and the area of measurement vary from study to study and therefore it is impossible to compare the results obtained by different authors and instruments.

For all of the above reasons, the aim of the present study was to determine the minimum number of measurements and the minimum area of measurement required, in relation to the dimensions of the measuring head, to quantify the color of a granite sample and to establish a methodology applicable to the determination of these parameters in other types of ornamental stone. This paper seeks to combine key aspects of colorimetry and using conventional statistical tools, however it must be stressed that there is still a lack of knowledge of the applicability of present color-difference formulas in color difference of heterogeneous surfaces and their correlation to visual judgments. In this line, despite the current interest in providing innovative color-difference formulas focused on the heterogeneous color surfaces and based on an improved understanding of the visual judgments, the success in this field has not yet been reached.

## Samples and equipment used

Two different instruments were used to measure the color, a GretagMacbeth portable spectrophotometer (CE-XTH), with two diameter viewing apertures of 5 and 10 mm, and a Minolta colorimeter, which has two measuring heads: CR-300 with 8 mm-diameter viewing area and CR-310 with 50 mm-diameter viewing area. A wide range of measurement areas was thus achieved with the two devices (circular areas of 5, 10, 8 and 50 mm diameter).

The same measuring conditions were fixed in both devices so that the measurements were comparable. The following were therefore selected: illuminant D65, which represents a phase of daylight, with a CCT of approximately 6500K, including the ultraviolet region spectrum, and 2-degree observer (CIE 1931). The measurements were made by spectral reflectance, using the diffuse illumination geometry with an integration sphere, covered with a white material, so that the light is uniformly diffuse in all directions illuminating the sample, and is observed with the specular component included in 8-degree in relation to normal (d/8º) in the case of the spectrophotometer and 0-degree (d/0º) in the case of the colorimeter (Fig. 1).

The color measurements were plotted in the CIELAB color space. The CIELAB system is since 1976 the most widely used system for calculating color differences for most practical applications. Use of the CIELAB system enables estimation of three classical color parameters: $L^*$, $a^*$ and $b^*$, where $L^*$ represents lightness, $a^*$ the position between red and green on the redness (+) to greenness (-) axis and $b^*$ the position between yellow and blue on the yellowness (+) to blueness (−) axis. The three parameters are plotted on three orthogonal axes in a Cartesian coordinate system. In addition, the classical CIEL*a*b* formula ($\Delta E^*_{ab}$) and two CIELAB-based color-difference formulae ($\Delta E_{94}$ and $\Delta E_{00}$) were applied.

Four varieties of ornamental granite with very different characteristics in terms of color and texture were selected: *Labrador Claro*, a bluish-black coarse-grained granite; *Grissal*, a grey medium-grained granite; *Rosa Porriño*, a pinkish, coarse-grained granite, and *Blanco Cristal*, a white, fine-grained granite. Samples of all varieties were prepared with 4 different types of finish, i.e. of increasing degree of roughness: polished, honed, sawn and flamed, except in *Labrador Claro* whose flamed finish is not easy to obtain. This set of samples was denominated *Granite Training group* because it comprised the reference samples. (Fig 2)

In order to determine the number of measurements required, 5 square specimens (surface area, 36 $cm^2$) of each variety of granite and type of finish were used. A total of 20 measurements with each of the four measurement heads, of 5, 8, 10 and 50 mm diameter were made consecutively with replacement at different points selected randomly on the surface of each square specimen.

In order to determine the minimum area that must be measured, the same conditions were used on 5 square specimens of the same and larger surface area (36, 54, 72 and 90 $cm^2$) of each variety of granite and type of finish.

Once the minimum area and number of measurements were determined, the validity of the results was tested with other ornamental granite commonly used as a building material, but of a different color from the four test varieties. The variety chosen for this was *Silvestre*, a fine-grained, lightly weathered granite, which has a brownish-gold color due to weathering of its minerals (Fig 2). The *Silvestre* variety of granite does not allow flamed or polished finish, therefore, they were substituted by bush hammered and polished without glow respectively.

Color measurements were made on specimens of this granite, denominated *Granite Test group* (Fig 2), in the same way as for the specimens in the *Granite Training group*.

All of the data were subjected to multivariate analysis of variance (MANOVA) by use of the SPSS statistical programme (version 15.0).

## Results

For each of the specimens in the *Granite Training group* the cumulative averages of the CIELAB color system coordinates: $L^*$, $a^*$ and $b^*$ were plotted. The general shape of the graphics obtained was an inverted exponential decay with a horizontal asymptote, this steady section corresponds to the number of measurements from which the mean become constant; consequently, the first point of this section of the curve represents the minimum number of measurements required to characterize the coordinates *L*, a** and *b** for each specimen. By way of example, the plots obtained for one of the specimens are shown in Fig. 3. In each of the three graphs the number of measurements, from which the horizontal asymptote is reached and the mean become constant, is indicated by a marked segment. It can be seen that the number of measurements is different for each of the coordinates (L*, a* and b*); in general the value of lightness coordinate L* is the first to stabilize, whereas for the other two coordinates, a* and b*, more measurements are generally required.

The data were subjected to a multivariate analysis of variance (MANOVA) with the minimum number of measurements determined for L*, a* and b* as dependent variables, and type of rock, surface finish and diameter of the instrument measurement head as independent variables. The results of the analysis revealed that the type of rock, the surface finish and the diameter of the measurement head and their interactions produced significantly different results in terms of the minimum number of measurements required to characterize L*, a* and b*. The results of the analysis, including Wilks' lambda, the F-factor, the level of significance and the number of degrees of freedom are shown in Table 1.

The largest number obtained for each measurement head was therefore taken as the minimum number required to characterize the color of each specimen. Thus, according to the values shown in Table 2, in which the number of measurements required to define the color of the specimens is shown in relation to the measurement head, the finish and type of rock, it was established that for textured samples the smaller the measured head larger number of measures are needed. So, for a measurement head of 50 mm diameter, 6 measurements/36 $cm^2$ are required, for measurement heads of 8 and 10 mm diameter, 14 measurements/36 $cm^2$ and for a measurement head of 5 mm diameter, 17 measurements /36 $cm^2$ are required (Table 2).

Once the minimum number of measurements required to characterize the color of granite rocks was established, the minimum area of measurement was determined. For this, five specimens of each type of granite and surface finish were prepared with different areas (36 $cm^2$, 54 $cm^2$, 72 $cm^2$ and 90 $cm^2$), on which the corresponding number of measurements were made for each area and measurement head, according to the results obtained in the previous paragraph and using the four different measurement heads (5, 8, 10 and 50 mm).

In order to determine whether the color varied with the measurement area, the data were subjected to MANOVA for each type of rock and measurement head (Table 3), with the mean values of $L^*$, $a^*$ and $b^*$ for each specimen as dependent variables and the measurement area (36, 54, 72 and 90 $cm^2$) as independent variable. As shown in Tables 3 and 4, there were statistically significant differences between the color obtained with the 50mm diameter measurement head for an area of 36 $cm^2$ and the other areas. According to these results, in order to characterize the color of granite, a measurement area of 36 $cm^2$ and 14 measurements with random replacement, is sufficient only if measurement heads of diameter ≤10 mm are used.

In order to determine the minimum area of measurement required with a 50 mm diameter measurement head, the statistical analysis was repeated with only the values of $L^*$, $a^*$ and $b^*$ obtained for areas greater than 36 $cm^2$, i.e., with those corresponding to areas of 54, 72 and 90 $cm^2$, and with those obtained for areas greater than 54 $cm^2$, i.e. with areas of 72 and 90 $cm^2$.

Comparison of the values obtained for areas larger than 36 $cm^2$ revealed statistically significant differences for *Grissal*, *Blanco Cristal* and *Labrador Claro* between the values obtained in an area of 54 $cm^2$ and those obtained in the other two areas (72 and 90 $cm^2$). However, there were no statistically significant differences between the values obtained for areas of 72 and 90 $cm^2$ (Table 5), and therefore it can be concluded that in order to characterize the color of granite when working with a 50 mm diameter measurement head, a minimum surface area of 72 $cm^2$ is required.

Once the number and area of measurement were established in relation to the dimensions of the measurement head, the color determined by each head was compared to establish whether the results obtained are comparable. Considering the previous results, only the data obtained for an area of 72 $cm^2$ were used, and the number of measurements required was 12, 28, 28 and 34 for measurement heads of 50, 10, 8 and 5 mm respectively.

The results of a MANOVA, with L*, a* and b* as dependent variables and the diameter of the measurement head as the independent variable revealed statistically significant differences between the values obtained with the difference measurement heads (Wilks' lambda: 0.949; F: 44,739; df: 9; significance: 0,000) with the 50 mm measurement head producing the greatest differences (Table 6).

With the aim of analysing the real significance, rather than the statistical significance, of the differences in color obtained with the 5, 8, 10 and 50 mm diameter measurement heads, the total color differences (ΔE) for pairs of measurement heads (Fig. 4) were calculated with the classical CIEL*a*b* formula ($\Delta E^*_{ab}$) and the CIELAB-based color-difference formulae ($\Delta E_{94}$ and $\Delta E_{00}$) and expressed in CIELAB units[13,14] and the more recent CIE94 and CIEDE2000 units,[10] respectively. The differences in color were calculated with the *Granite Training group*, in order to obtain generalizable results. The results obtained (Fig.4) show that the differences in color measured in CIEDE2000 and

CIE94 units, which clearly improve on the CIELAB units[15,16,17] and are more appropriate for evaluating samples with low chromaticity values,[18] were the same as or lower in magnitude than the CIELAB measurements. It was also found that there was no equivalence of scale factor among the values produced with the three formulae considered. The visual color difference threshold or just noticeable difference (jnd), which constitutes the lower limit of perception in a individual with normal color vision[19,20,21] and that it can be established as 0.73 CIELAB units,[22,23] is also shown in the Figure 4. Below this value, the differences in color are inappreciable and therefore the colors determined with the 8 and 10 mm measurement heads would be considered identical by an observer. However, if the suprathreshold color-difference, which is approximately 1.75 CIELAB units[15] is taken into account, all of the values of the total color differences (ΔE) for pairs of measurement heads are below this value and are only outshined in the case of the color differences for the 8 and the 50 mm measurement heads, which were measured with the same device (the Minolta colorimeter). These two measurement heads provided the greatest differences in the total color differences (ΔE) from the three measurements used: $\Delta E^*_{ab}$, $\Delta E_{94}$ and $\Delta E_{00}$.

On the other hand, if we take into account the color tolerances or units of color differences applied in the industrial field, where larger color differences are used, all of the values of ΔE obtained for the different measurement head were lower than 3 CIELAB units, the value considered as the upper limit of rigorous color tolerance.[14,24]

With the aim of standardizing the results obtained with the granites included in the *Granite Training group*, a test was carried out to determine whether these were applicable to other granites. For this, the color of one of the granites most commonly used at present in the building industry for cladding and for constructing monuments -a brownish gold granite denominated *Silvestre*- was determined.

The values obtained for this granite (for an area of 72 $cm^2$ and number of measurements depending on the measurement head used: 34/ 5 mm head, 28/ 8 and 10 mm head, 12/ 50 mm head) were subjected to MANOVA, with L*, a* and b* as dependent variables and the diameter of the measurement head (5, 8, 10 and 50 mm) as the fixed factor. The results were similar to those obtained with the *Granite Training group*; there were statistically significant differences in relation to the measurement head (Wilks' lambda: 0.865, F: 33.843; df:9; sig:0.000) for each of the parameters considered (Table 7). The total color differences (ΔE) were calculated for the different measurement heads (Fig.5) and a rigorous color tolerance (i.e. < 3 CIELAB units) was obtained. Again, the greatest difference was between the color measurements made with the measurement heads of 50 mm and 8 mm diameter. The total color difference $\Delta E^*_{ab}$ comparing small heads (5-10 and 5-8 mm) decreased by approximately 0.5 CIELAB units in relation to the results obtained with the *Granite Training group*, whereas any comparison ($\Delta E^*_{ab}$, $\Delta E_{94}$ and $\Delta E_{00}$) between the 50 mm and the 5 mm measurement heads caused an increase in the difference of 0.5 CIELAB units and of 1 CIELAB unit when the comparison was between the 50 mm and the 8 or 10 mm measurement heads.

Finally, it must be underlined that a future research in this field would be focussed on performing visual experiments using psychophysical techniques with the aim of defining the granitic rocks threshold data. These thresholds will allow a better understanding of the color differences in granite rocks.

## Conclusions

This work provides an adaptable and affordable methodology of study supported by statistical analysis, which has been successful in examination the factor affecting the color measurements on granite rocks and demonstration that color may be affected by both material and instruments properties. In this way, the methodology used enabled the determination of the minimum number of measurements and the minimum measuring area required to characterize the representative color of the whole non-homogeneous surface of granite rocks. However, little attention has been paid to the validity of present color-difference formulas applied to heterogeneous surfaces, such as granite rocks, pending developments of the visual assessment.

In relation to the minimum number of measurements required to characterize the color of granite rocks, it was found that it is affected by the type of rock, surface finish and, independently of the rock, by the diameter of the measurement head of the device. By use of a wide variety of granite rocks that differ in terms of color, texture and surface finish, it was determined that the minimum number of measurements required to characterize the color of granitic rocks is higher the smaller the measurement head. Thus, the number of measurements required is 6/36 $cm^2$ surface area for a 50 mm diameter measurement head, 14/36 $cm^2$ for 8 and 10 mm diameter measurement heads, and 17/36$cm^2$ for a 5 mm measurement head.

As regards the minimum measuring area, the results showed that an area of 36 $cm^2$ is sufficient when measurement heads of diameter $\leq$10 mm are used. A surface area equal to or larger than 72 $cm^2$ is required for measurement heads of larger diameters.

The validity of the above results was tested with other ornamental granite (*Granite Test group*) allowing conclude that if and when the number of measurements considered corresponds to that established in this study for the measurement head diameter and the measurement area, any results thus obtained will be comparable.

As granite rocks can be considered as a complicated case of surface heterogeneity due to the complexity of their mineral distribution, it could be hypothesized that the methodology here proposed can be extrapolated to other types of rocks.

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**Figure 1.** Schematic view of a diffuse illumination geometry 0º (d/0º) –right- and diffuse illumination geometry 8º (d/8º) - left.

Figure 2. Granite specimens used in the study. Granite Training group: specimens in the same row are of the same type, from above to below: Blanco Cristal, Grissal, Rosa Porriño and Labrador Claro. Specimens in the same column have the same finish, from left to right: polished, honed, sawn and flamed. Granite Test group: Silvestre, from above to below: polished without glow, honed sawn and bush hammered.

**Figure 3.** Example of the graphs used to determine the minimum number of measurements required. Cumulative averages for parameters L*, a*, b* in relation to the number of measurements made in one specimen of the Rosa Porriño granite with the 8 mm measurement head. The marked segment indicates the minimum number of measurements required.

**Figure 4.** Total color differences for Granite Training group, in CIELAB units (ΔE*ab), CIE94 units (ΔE94) and CIEDE2000 units (ΔE00), obtained with different pairs of measurement heads.

**Figure 5.** Total color differences for Granite Test group (Silvestre), in CIELAB units (ΔE*ab), CIE94 units (ΔE94) and CIEDE2000 units (ΔE00), obtained with different pairs of measurement heads.

Figure 1.

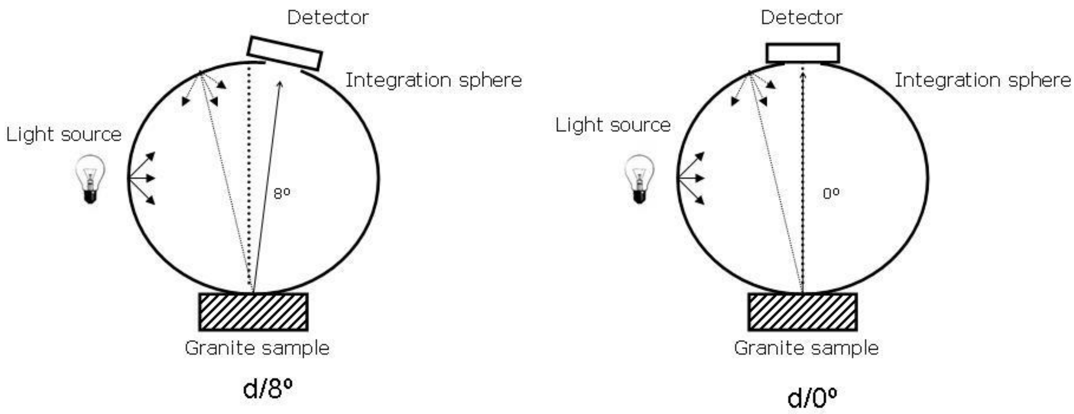
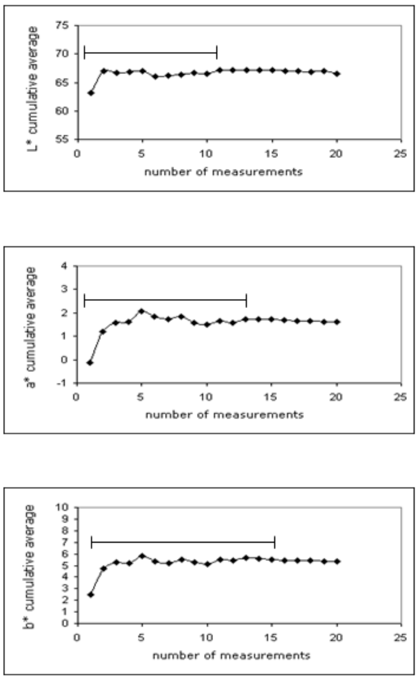

Detector
Integration sphere
Light source
8º
Granite sample
d/8º
Detector
Integration sphere
Light source
0º
Granite sample
d/0º

Figure 2.

Figure 3.



L* cumulative average
number of measurements
a* cumulative average
number of measurements
b* cumulative average
number of measurements

Figure 4.

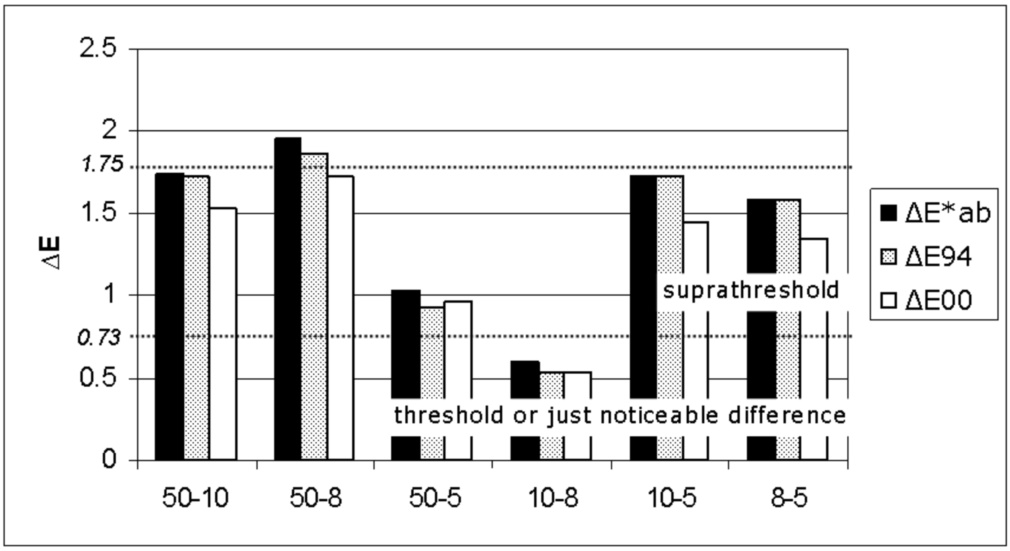

2.5
2
1.75
1.5
1
0.73
0.5
0
ΔE
50-10
50-8
50-5
10-8
10-5
8-5
suprathreshold
threshold or just noticeable difference
ΔE*ab
ΔE94
ΔE00

Figure 5.

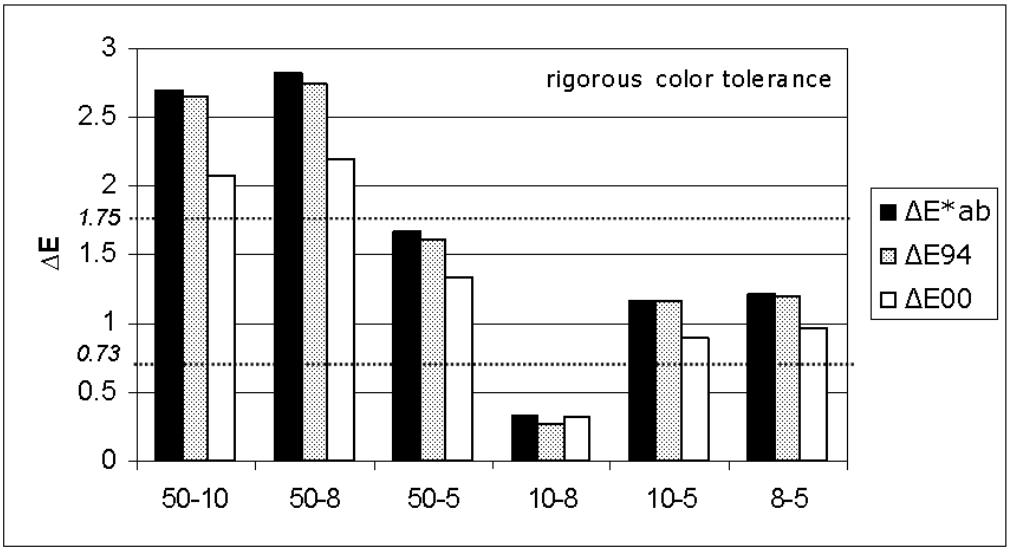

3
2.5
2
1.75
1.5
1
0.73
0.5
0
ΔE
rigorous color tolerance
ΔE*ab
ΔE94
ΔE00
50-10
50-8
50-5
10-8
10-5
8-5

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**Table2.** Minimum number of measurements in relation to the measurement head, surface finish and type of granite.

**Table3.** Three-way multivariate analysis of variance (MANOVA) for the measurement area in relation to the size of the measurement head.

**Table4.** Tukey-b test for the 50 mm diameter measurement head.

**Table5.** Three-way multivariate analysis of variance (MANOVA) comparing the different areas measured.

**Table6.** Tukey-b test for the four measurement heads.

**Table7.** Tukey-b test for the four measurement heads and *Silvestre* granite.

**Table1.**

| Source | Wilk's lambda | F-value | df. | Significance. |
|---|---|---|---|---|
| Type of rock (granite) | 0.625 | 13.663 | 9 | .000 |
| Surface finish | 0.678 | 11.093 | 9 | .000 |
| Target area | 0.123 | 87.715 | 9 | .000 |
| Type of rock * Surface finish | 0.594 | 5.645 | 24 | .000 |
| Type of rock * Target area | 0.637 | 4.282 | 27 | .000 |
| Surface finish * Target area | 0.729 | 2.933 | 27 | .000 |
| Type of rock * Surface finish * Target area | 0.487 | 2.681 | 72 | .000 |

Dependent: L*, a*, b*.

**Table2.**

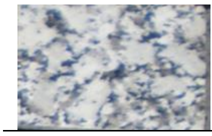
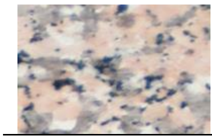
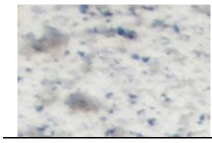
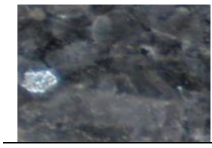
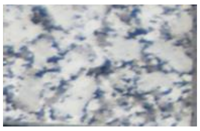
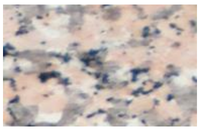
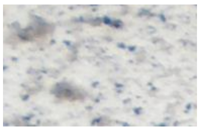
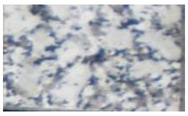
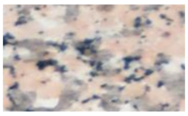
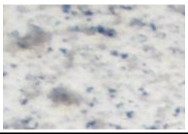
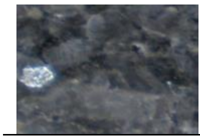
| Type of rock (granite) | Surface finish | Target area (mm) | | | |
|---|---|---|---|---|---|
| | | **50** | **10** | **8** | **5** |
| Grissal | Flamed | 4 | 11 | 12 | 14 |
|  | Sawn | 1 | 10 | 11 | 15 |
| | Honed | 2 | 14 | 14 | 17 |
| | Polished | 1 | 6 | 12 | 17 |
| Rosa Porriño | Flamed | 3 | 13 | 14 | 15 |
|  | Sawn | 2 | 9 | 13 | 16 |
| | Honed | 6 | 13 | 9 | 10 |
| | Polished | 3 | 13 | 13 | 17 |
| Blanco cristal | Flamed | 1 | 14 | 14 | 17 |
|  | Sawn | 5 | 11 | 12 | 15 |
| | Honed | 1 | 12 | 13 | 17 |
| | Polished | 4 | 13 | 14 | 17 |
| Labrador claro | Sawn | 4 | 8 | 12 | 14 |
|  | Honed | 4 | 11 | 13 | 17 |
| | Polished | 5 | 13 | 11 | 15 |

**Table3.**

| Type of rock (granite) | Target area (mm) | Wilk's lambda | F-value | df. | Significance |
|---|---|---|---|---|---|
| Grissal | 5 | 0.996 | 0.032 | 9 | 1.000 |
|  | 8 | 1.000 | 0.003 | 9 | 1.000 |
| | 10 | 1.000 | 0.004 | 9 | 1.000 |
| | 50 | 0.004 | 172.529 | 9 | 0.000 |
| Rosa Porriño | 5 | 0.984 | 0.133 | 9 | 0.999 |
|  | 8 | 0.998 | 0.013 | 9 | 1.000 |
| | 10 | 0.998 | 0.013 | 9 | 1.000 |
| | 50 | 0.009 | 118.037 | 9 | 0.000 |
| Blanco Cristal | 5 | 0.984 | 0.130 | 9 | 0.999 |
|  | 8 | 1.000 | 0.003 | 9 | 1.000 |
| | 10 | 0.999 | 0.006 | 9 | 1.000 |
| | 50 | 0.427 | 8.378 | 9 | 0.000 |
| Labrador Claro | 5 | 0.999 | 0.006 | 9 | 1.000 |
|  | 8 | 0.998 | 0.011 | 9 | 1.000 |
| | 10 | 0.999 | 0.007 | 9 | 1.000 |
| | 50 | 0.473 | 5.265 | 9 | 0.000 |

Dependent: L*, a*, b*.

**Table4.**

| Type of rock (granite) | Area ($cm^2$) | L* | a* | b* |
|---|---|---|---|---|
| Grissal | 36 | $57.02^{a}$ | $3.88^{a}$ | $-8.49^{a}$ |
|  | 54 | $64.07^{b}$ | $-0.75^{b}$ | $0.86^{b}$ |
| | 72 | $64.08^{b}$ | $-0.54^{c}$ | $0.79^{b}$ |
| | 90 | $63.48^{b}$ | $-0.54^{c}$ | $0.78^{b}$ |
| Rosa Porriño | 36 | $57.45^{a}$ | $5.91^{a}$ | $-3.67^{a}$ |
|  | 54 | $63.89^{b}$ | $2.20^{b}$ | $5.63^{b}$ |
| | 72 | $63.91^{b}$ | $2.33^{b}$ | $5.68^{b}$ |
| | 90 | $63.93^{b}$ | $2.34^{b}$ | $5.70^{b}$ |
| Blanco Cristal | 36 | $68.05^{a}$ | $2.75^{a}$ | $-3.42^{a}$ |
|  | 54 | $72.38^{b}$ | $-0.28^{b}$ | $3.13^{b}$ |
| | 72 | $71.96^{b}$ | $-0.11^{b}$ | $2.72^{b}$ |
| | 90 | $71.34^{b}$ | $-0.10^{b}$ | $2.72^{b}$ |
| Labrador Claro | 36 | $48.28^{a}$ | $-0.49^{a}$ | $-1.32^{a}$ |
|  | 54 | $48.05^{ab}$ | $-0.40^{ab}$ | $-1.34^{a}$ |
| | 72 | $47.75^{b}$ | $-0.28^{b}$ | $-1.42^{a}$ |
| | 90 | $47.74^{b}$ | $-0.28^{b}$ | $-1.42^{a}$ |

Different superscript letters in each column for each granite indicate significant differences ($\alpha$:0.05)

**Table5.**

| Type of rock (granite) | Areas (cm2) | Wilk's lambda | F-value | df. | Significance |
|---|---|---|---|---|---|
| Grissal | 54-72-90 | 0.511 | 7.313 | 6 | 0.000 |
| | 72-90 | 0.981 | 0.227 | 3 | 0.877 |
| Rosa Porriño | 54-72-90 | 0.958 | 0.396 | 6 | 0.880 |
| Blanco Cristal | 54-72-90 | 0.581 | 5.712 | 6 | 0.000 |
| | 72-90 | 0.969 | 0.388 | 3 | 0.762 |
| Labrador Claro | 54-72-90 | 0.615 | 3.662 | 6 | 0.003 |
| | 72-90 | 0.999 | 0.002 | 3 | 0.999 |

Dependent: L*, a*, b*.

**Table6.**

| Diameter of measurement head (mm) | L* | a* | b* |
|---|---|---|---|
| 50 | $62.87^{a}$ | $0.39^{a}$ | $2.17^{a}$ |
| 10 | $64.45^{b}$ | $0.08^{b}$ | $2.84^{b}$ |
| 8 | $64.32^{b}$ | $0.06^{b}$ | $3.43^{c}$ |
| 5 | $62.76^{a}$ | $0.18^{b}$ | $3.17^{c}$ |

Different superscript letters in each column indicate significant differences ($\alpha$:0.05)

**Table7.**

| Diameter of measurement head (mm) | L* | a* | b* |
|---|---|---|---|
| 50 | $70.02^{a}$ | $-0.04^{a}$ | $3.48^{a}$ |
| 10 | $72.56^{b}$ | $-0.11^{b}$ | $4.37^{b}$ |
| 8 | $72.56^{b}$ | $-0.24^{c}$ | 4.68 |
| 5 | $71.41^{c}$ | $0.02^{d}$ | $4.41^{b}$ |

Different superscript letters in each column indicate significant differences ($\alpha$:0.05)