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Mineralogia. — *Macrohardness derivation from microhardness measurements.* Nota di MARCO FRANZINI e MIRELLA TROYSI (*), presentata (**) dal Socio G. CAROBBI.

RIASSUNTO. — Si suggerisce un metodo analitico e/o grafico di trattamento dei valori di microdurezza Vickers misurati con diversi carichi su di uno stesso materiale. Nell'ipotesi che le variazioni di microdurezza in funzione del carico siano dovute ad un ritiro elastico dell'impronta, il metodo suggerito consente la valutazione di un valore di microdurezza estrapolata indipendente dal carico. Tale valore rappresenta una buona approssimazione della macrodurezza.

INTRODUCTION

It is well known that the measured values of indentation microhardness appear to decrease as the load increases; this fact holds true both in isotropic and in crystalline materials (monocrystals as well as microcrystalline aggregates characterized by single grains smaller than indentations).

However experimental data suggest that it is possible to derive an extrapolated hardness value independent of load by adding to the measured diagonal lengths a σ value, independent of load and characteristic of the material on which the test was carried out. The following empirical relationship was suggested by Franzini [1] and later applied by Leoni and Petracco [2]:

$$\text{HV}_E = \frac{K \cdot p}{(d_p + \sigma)^2} \tag{1}$$

where HV_E represents the extrapolated hardness values, K is a constant the value of which depends on the particular indenter, σ is the fixed value added to the measured diagonal (d_p) of the indentation and p is the applied load.

The authors of the present paper will illustrate the physical meaning of this relationship in a future contribution; they will now simply show the pratical derivation of the HV_E and σ values from two or more measurements obtained at different loads utilizing the Vickers pyramid. Within the error limits expected from the measurement techniques, HV_E may be identified with macrohardness.

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(**) Nella seduta del 10 novembre 1978.

THEORY

The Vickers microhardness value (HV_p) for a particular loading (p) is calculated from the following equation:

$$HV_p = \frac{K \cdot p}{(d_p)^2} \tag{2}$$

From equations (1) and (2), equation (3) can be derived:

$$\frac{1}{\sqrt{HV_E}} - \frac{\sigma}{\sqrt{K \cdot p}} = \frac{1}{\sqrt{HV_p}} . \tag{3}$$

Equation (3) is a linear one with two unknowns involved: $1/\sqrt{HV_E}$ and σ. If n measurements are taken for different loads, a system of n linear equations may be written; such a system can be solved by the normal regression methods for $1/\sqrt{HV_E}$ (i.e. for HV_E) and σ.

Obviously, expression (3) being a linear equation, HV_E and σ values can also be obtained by graphic methods. A graph of load values against Vickers hardness numers should be prepared; the abscissa scale, where the load values are plotted, must be calculated from the formula:

$$x_p = X \sqrt{p_{min}/p} \tag{4}$$

where X is the interval (measured, for example, in mm) assumed to represent a range of loads from a minimum value (p_{min}) to infinity, while x_p is the abscissa value to which a particular load (p) plots.

For example, if we assume X = 200 mm and p_{min} = 15 g, we have:

p (g)	15	25	50	100	200	300	500	∞
x_p (mm)	200	154.92	109.54	77.46	54.77	44.72	34.64	0

Likewise the scale of the ordinate, where the measured microhardness values are plotted, must be derived from the formula:

$$y_{HV} = Y \sqrt{HV_{min}/HV} . \tag{5}$$

In such a graph the microhardness values measured at different loads will align along a straight line (eqn. 3), the extrapolated intercept of which with the ordinate axis gives the value of HV_E. Since the slope of the straight line would allow derivation of the σ value, the values assumed for X and Y in the equations (4) and (5) cannot be independent. If x_1 , x_2 , y_1 , y_2 are the abscissae and the ordinates of two points read from a graph drawn on a linear scale basis, then from equations (3), (4) and (5) we will have:

$$\sigma = \frac{X \sqrt{K \cdot p_{min}}}{Y \sqrt{HV_{min}}} \cdot \frac{(y_1 - y_2)}{(x_1 - x_2)} . \tag{6}$$

In order to immediately derive σ from the straight-line slope it is more convenient to assume the constant

$$M = \frac{X \sqrt{K \cdot p_{\min}}}{Y \sqrt{HV_{\min}}} \tag{7}$$

equal to a simple number (i.e. 0.5, 1, 2) Now from equation (7) we can obtain the relationship between the two parameters X and Y:

$$Y = X \frac{\sqrt{K \cdot p_{\min}}}{M \sqrt{HV_{\min}}} . \tag{8}$$

Moreover, combining equation (5) and equation (8) we have:

$$y_{HV} = X \frac{\sqrt{K \cdot p_{\min}}}{M \sqrt{HV}} . \tag{9}$$

Since this expression gives a series of values of y_{HV} decreasing as HV increases, it is more convenient to apply to the following expression: $y_{HV} = A - y_{HV}$.

In order to make the scale of hardnesses begin with a minimum established value ($HV_{\min}$), it is suitable to define A as:

$$A = \frac{X \sqrt{K \cdot p_{\min}}}{M \sqrt{HV_{\min}}} \tag{10}$$

this consequently leads to the expression:

$$y'_{HV} = \frac{X}{M} \cdot \sqrt{K \cdot p_{\min}} \cdot \left(\frac{1}{\sqrt{HV_{\min}}} - \frac{1}{\sqrt{HV}} \right) . \tag{11}$$

For example, if, we assume X = 200 mm, K = 1854.4, $P_{\min} = 15$ g, M = 2, $HV_{\min} = 70$ Kg/mm², then we obtain:

HV (Kg/mm²)	70	71	72	75	80
y_{HV}	0	14.09	27.88	67.59	128.75 .

From equation (3) and from inspection of the graph illustrated in Fig. 1 it is easy to see that:

$$HV_E = HV_{4p} - (HV_p - HV_{4p}) = 2\, HV_{4p} - HV_p \tag{12}$$

where HV_{4p} and HV_p are Vickers microhardness values, the former being obtained with a load 4 times greater than that applied for the latter measurement.

For example: $HV_E = 2\, HV_{0.1} - HV_{0.025}$.

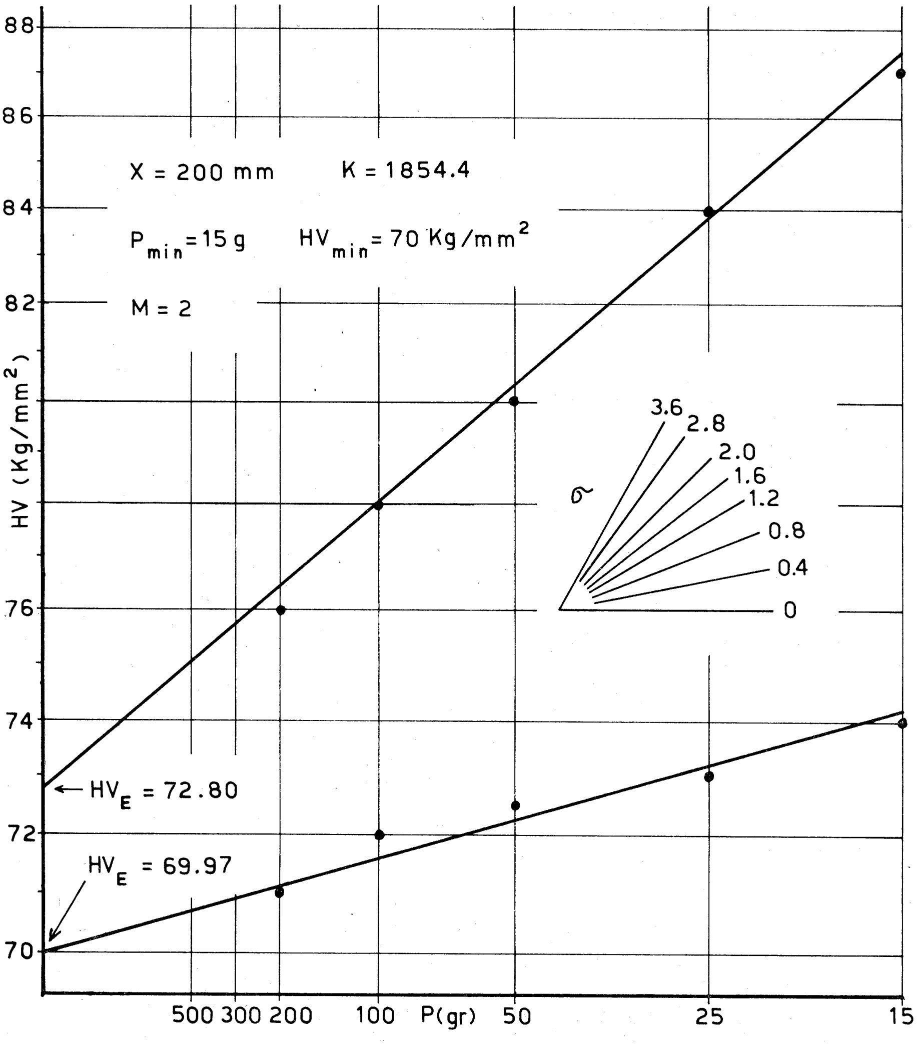

Fig. 1.

To sum up, there are two alternative ways of deriving HV_E and σ from a series of n measurements obtained with different loads applied:

a) algebraic solution of a system of n equations of the equation (3) type;

b) reference to graphs like that illustrated in Fig. 1.

A still more simplified way of deriving HV_E is offered by the use of equation (12).

APPLICATION

The measurements of two galena samples (Table I) are reported as an example.

TABLE I.

P (*g*)	Bottino mine			Freiberg mine		
	d (μm)	HV (Kg/mm²)	HV_{cal}	d	HV	HV_{cal}
15	17.8	87	72.97	19.4	74	69.73
25	23.5	84	72.86	25.2	73	69.80
50	34.1	80	72.25	35.8	72.5	70.09
100	48.6	78	73.22	50.8	72	70.27
200	69.7	76	72.70	72.3	71	69.84
	$HV_E = 72.80$ $\sigma = 1.72$ d.s. $= 0.32$ $HV_{25-100} = 72$ $HV_{50-200} = 72$			$HV_E = 69.97$ $\sigma = 0.57$ d.s. $= 0.19$ $HV_{25-100} = 71$ $HV_{50-200} = 69.5$		

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