Πρακτικά 6ου Συνεδρίου		Μάιος 1992	
Δελτ.Ελλ.Γεωλ.Εταιρ.	Τομ. XXVIII/3	σελ. 349-358	Αθήνα 1993
Bull.Geol.Soc.Greece	Vol.	pag.	Athens

ABRASION LOSS OF WEIGHT AS HARDNESS EXPRESSION OF ROCKS. APPLICATION ON THE OPHIOLITES OF CHALCIDIKI / GREECE.

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ABSTRACT

Hardness of rocks can be expressed by the "abrasion loss of weight (AR)" as a measure of their mechanical behaviour and their ability to resist weathering. The method used is based on the calculation of the loss of weight of a pre-weighted sample after abrasion for a constant time under constant conditions. For this purpose a LOGITECH - LP 30 thin section lapping machine is used.

Twenty specimens of gabbros and peridotite from Chalcidiki peninsula (N. Greece) are used for the tests. Relationships between the abrasion loss of weight (AR, ⁻%) and properties such as dry density (d, gr/cc) and ultrasonic velocity (vp, m/msec) are determined, confirming the precision of the method.

For sound rocks the existing relationships could be expressed by linear regressions. Yet, in weathered materials, especially in multiphase rocks, the rate of change of the abrasion loss of weight increases more quickly than the decrease of the dry density and the ultrasonic velocity. An exponential regression could express better the existing relationships in case that tests cover a big range of values, from sound to weathered specimens.

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INTRODUCTION

Hardness express the ability of rocks to resist tracing and abrasion. It is a characteristic mechanical property of solids due to the forces among atoms, that join together. Thus, there are hard rocks, which are not traced, and soft rocks which are friable and can be traced easily.

Hardness is directly related to properties such as compression strength, ultrasonic velocity, dry density, drilling velocity, damage of building stones, etc. (Hunt, 1984).

The purpose of this investigation is the quantitative approach, of Hardness, as "abrasion loss of weight" after lapping of the rock specimens, under constant conditions, using a thin section lapping machine. The definition of the parameters used, insure the repetition of the method. The correlation of test results with other characteristic properties confirms the precision of the method.

SAMPLING AND METHODS OF STUDY

Concerning the quantitative determination of hardness, several indirect methods have been described in the past, since no direct determination is possible. These methods are referred to a) the resistance of the rock to tracing (Knoop method [National Bureau of Standards, USA {Verfel, 1989}]), b) the rebound of a falling little ball, with a diamond or hard metal edge (Shore method {Tsoutrelis, 1968}) c) the resistance to abrasion and striking (Los Angeles method {ASTM C 131 - 47, Jonson & DeGraff, 1988}) and d) the resistance to abrasion (ASTM C 241 - 85).

The method used in the present study, can be characterised similar to the abrasion resistance method of ASTM C 241 - 85 specification and referred to the determination of the abrasion loss of weight of a specimen after lapping. Test are performed using a thin section lapping machine, instead of the classic abrasion machine, preview in the previous relative specification.

Tests were applied on 20 ophiolitic specimens, 10 gabbros and 10 peridotite, from the surrounding area of Gerakini village, in Chalcidiki peninsula (Fig. 1). Samples 1 - 10 correspond to gabbros while samples 11 - 20 correspond to peridotite.

Samples were studied regarding to their hardness as well as to their dry density and the ultrasonic velocity. the specimens used were selected carefully, to be compact and without fractures. Test results are presented in Table 1.

The tests of dry density and ultrasonic velocity were applied on mini cores of 24 mm diameter and 48 mm high. The "abrasion loss of weight" tests were applied on mini cores of 10 mm high, cut from those of the previous tests. This reduction of hight was necessary for the following reasons: **a)** To avoid a possible damage of specimens. Specimens were very high in relation to their diameter, causing an unstable equilibrium with probable toppling and fragmentation, during operation, **b)** Only the lower surface is polished, during lapping operation. So, this reduction of hight was necessary, in order to obtain a more representative value of the loss of weight in relation to the total weight.

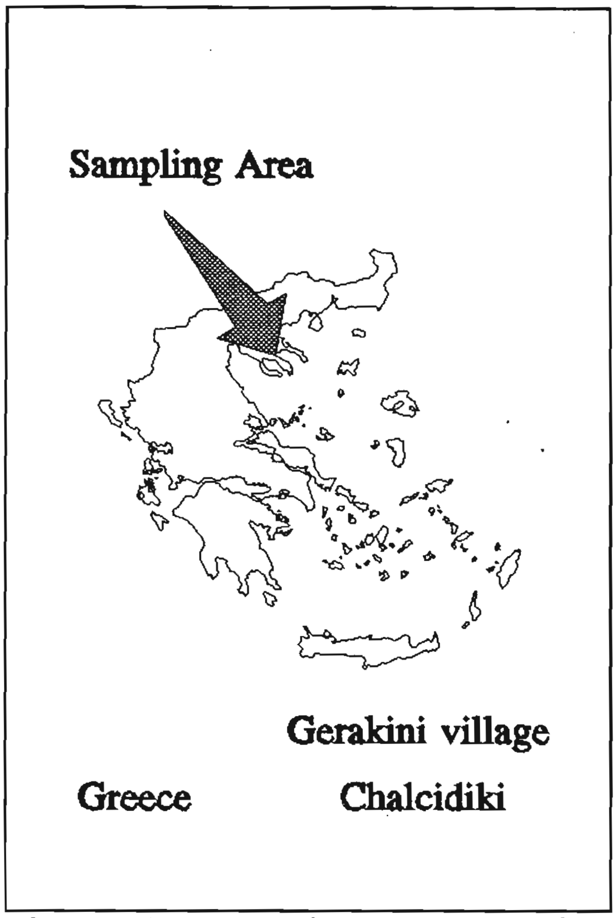

Figure 1. Location of sampling area (Gerakini, Chalcidiki).

<u>**HARDNESS:**</u> Hardness was measured as "abrasion loss of weight (AR, %). It is the difference of weight before and after abrasion of specimens, expressed as a percentage of total weight. Tests were performed using a LOGITECH - LP30 thin section lapping machine (Fig. 2). The abrasion time was precised to 1/2 h, with constant rotation of 40 rpm. The polishing material (sand) was emery No 400, in 1:10 water solution. The flow of the solution was 1 - 2 drops per revolution. Specimens were located in a cylindric catcher and loaded with 2 Kg.

Table 1. Test results of dry density (d), abrasion loss of weight (AR) and ultrasonic velocity (vp). Specimens from No 1 to 10 were gabbros and from No 11 to 20 peridotite. All specimens were collected from the ophiolites of Chalcidiki peninsula.

No	d (gr/cc)	AR (%)	vp (m/msec)
1	2.845	1.28	5.84
2	2.889	0.89	6.03
3	2.800	0.98	5.82
4	3.005	0.65	6.62
5	2.862	1.16	6.10
6	3.044	0.65	6.66
7	2.827	1.31	5.94
8	2.857	1.00	6.18
9	2.932	0.89	6.41
10	2.908	1.12	5.97
11	2.769	1.24	5.94
12	2.774	1.69	5.82
13	2.793	1.18	5.78
14	2.755	1.60	5.74
15	2.840	1.37	5.90
16	2.806	1.62	5.78
17	2.872	1.07	6.04
18	2.792	1.33	5.70
19	2.796	1.44	5.87
20	2.848	1.07	5.92

The calculated mean values of the abrasion loss of weight are AR= 0.993 % (std. dev., σ_{n-1}= 0.232) for the gabbros and AR= 1.361 % (std. dev., σ_{n-1}= 0.225) for the peridotite. The total mean value for the ophiolitic specimens was AR= 1.177 % (std. dev., σ_{n-1}= 0.292).

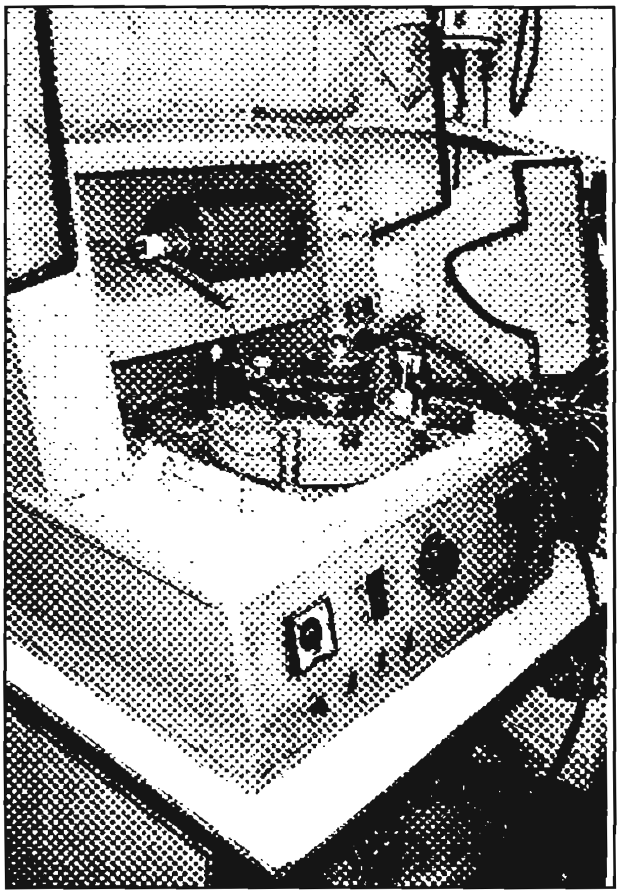

Figure 2. LOGITECH - LP30 thin section lapping machine.

DRY DENSITY (d, gr/cc, ASTM C 97 - 47): It was obtained by dividing the dry weight of the specimens by the total volume (solids and voids), after drying for 24 h, at 110^{0}C. The calculated mean values of dry density were d= 2.897 gr/cc (std. dev. σ_{n-1}= 0.078 for the gabbros and d= 2.804 gr/cc for the peridotite. The total mean value for the ophiolitic rocks was calculated as d= 2.851 gr/cc (std. dev., σ_{n-1}= 0.076.

ULTRASONIC VELOCITY (vp, m/msec, ASTM 597, ASTM D 2845 - 83): It is a good index characteristic of the physico-mechanical behaviour of the rocks. Measurements were performed using a PUNDIT portable ultrasonic non-destructive digital tester. The calculated mean values were vp= 6.157 m/msec (std. dev., σ_{n-1}= 0.307) for the gabbros and vp= 5.841 m/msec (std. dev., σ_{n-1}= 0.107) for the peridotite. The calculated total mean value was vp= 6.003 m/msec (std. dev., σ_{n-1}= 0.273).

INTERPRETATION OF TEST RESULTS

Test results were interpreted statistically concerning the relationship between the studied properties. These relationships were expressed mathematically (Table 2) and by regression diagrams, given in Figures 3, 4, 5. Correlation coefficients as well as standard

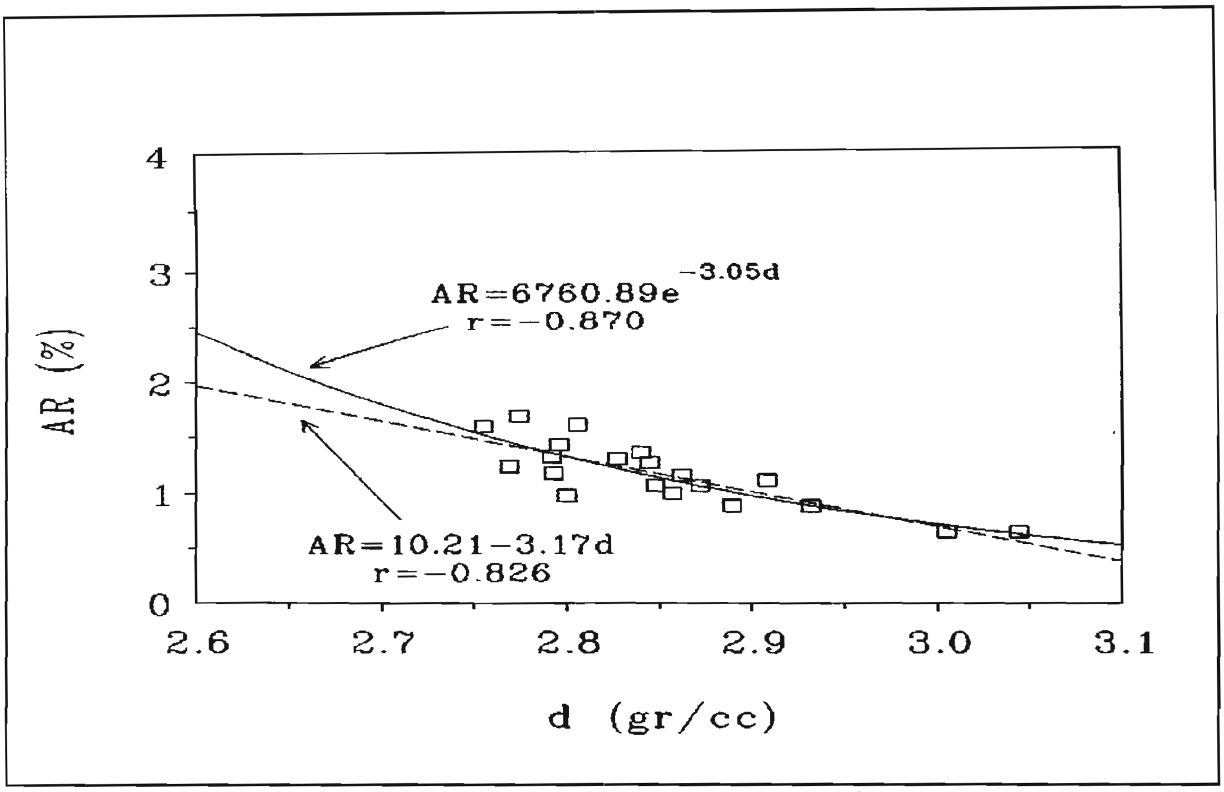

Figure 3. Regression diagram between dry density (d) and abrasion loss of weight (AR).

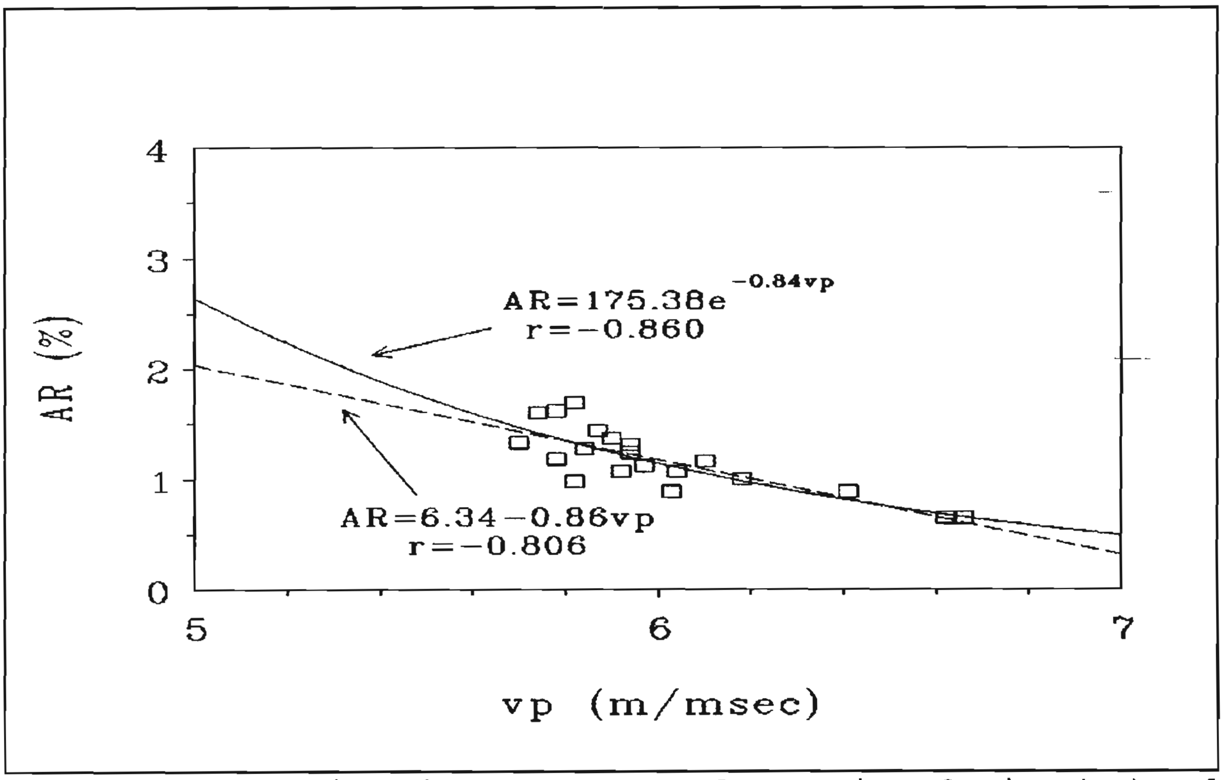

Figure 4. Regression diagram between ultrasonic velocity (vp) and abrasion loss of weight (AR).

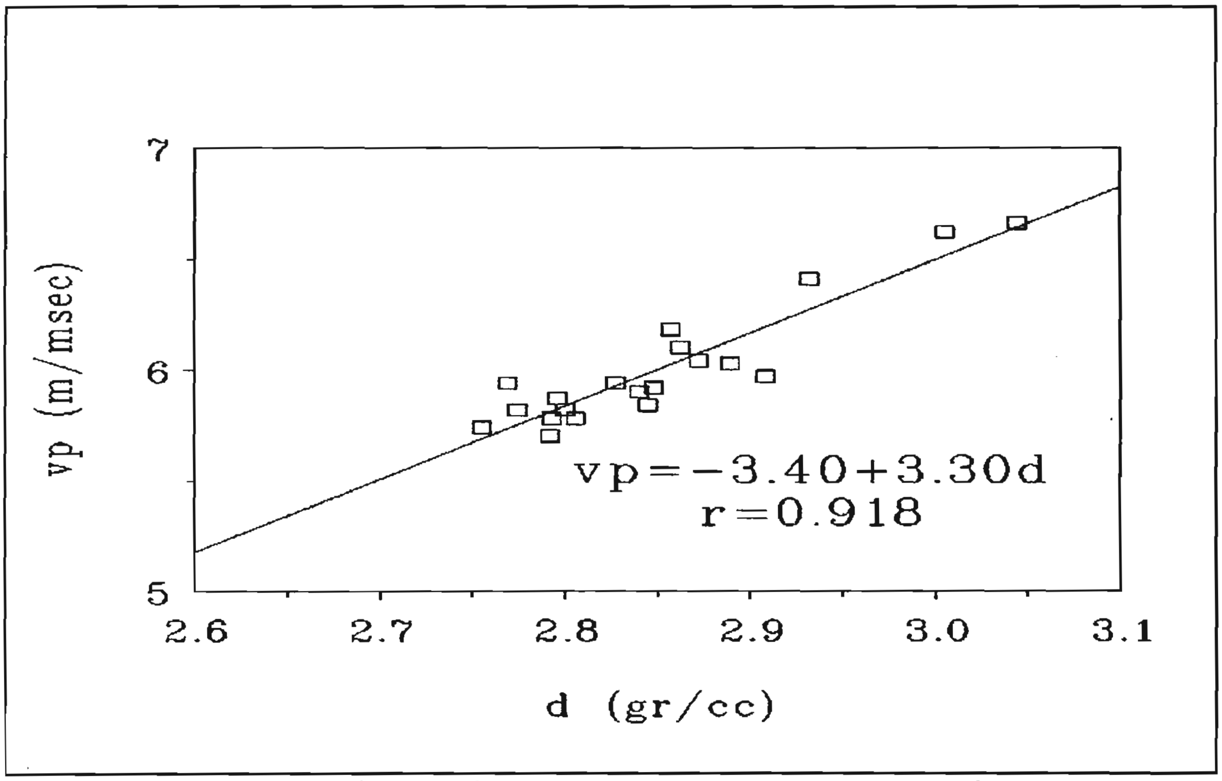

Figure 5. Regression diagram between dry density (d) and ultrasonic velocity (vp).

Table 3. Relationships between abrasion loss of weight and dry density (d) as well as ultrasonic velocity (vp), in sandstones (S) and limestones (L), from Epirus (Greece, Christaras, 1991).

S/L	Regression X - Y Size [S:20, L:10]	Correl. Coef.	Standard Dev. Y	Standard Error Y	Confid. 95%, Y	Confid. 99%, Y
S	Ab=10.41-3,62d	-0.9772	0.7915	0.1770	0.3469	0.4566
L	Ab=1.81-0.55d	-0.9821	0.0403	0.0128	0.0250	0.0329
S	$AR=6.75d^{-1.23}$	-0.9883	0.3127	0.0699	0.1370	0.1804
L	$AR=195.5d^{-3.99}$	-0.9623	0.4400	0.1391	0.2727	0.3590
S	vp=-5169+3082d	0.9079	726.13	162.37	318.24	418.91
L	vp=-13749+6648d	0.9771	485.14	153.42	300.69	395.81
S	$vp=32016AR^{-3.25}$	-0.9354	726.13	162.37	318.24	418.91
L	$vp=17765AR^{-1}$	-0.9514	485.14	153.42	300.69	395.81

Our previous investigations, on compact limestones and sandstones from Epirus (Table 3, Christaras, 1991) as well as on biogenic and marly limestones from Crete (Table 4, Moraiti & Christaras, 1991), showed that abrasion loss of weight is related to dry density and ultrasonic velocity by exponential regressions, similar to these of the present study.

Table 4. Relationships between abrasion loss of weight (AR) and ultrasonic velocity (vp), in marly and biogenic limestones from Crete (Greece, Moraiti & Christaras, 1991).

Equation	r	mean	min	max	r_{n-1}	St.Err.	Conf99%
Marly L.							
$AR=20.74vp^{-1.11}$	-0.997	5.03	4.11	6.87	0.75	0.17	0.43
Biogenic L.							
$AR=16.42vp^{-1.07}$	-0.986	4.72	3.85	5.75	0.62	0.14	0.3

CONCLUSION

In the present investigation, twenty cylindric specimens were studied concerning their hardness, dry density and ultrasonic velocity. Hardness was expressed as abrasion loss of weight and tests were performed using a thin section lapping machine.

The high significant relationship that present abrasion loss of weight with dry density and ultrasonic velocity, make test results worthy of credit and hardness data comparable.

The statistical interpretation showed that in sound rocks the existed relationship of abrasion loss of weight with dry density and ultrasonic velocity can be expressed by linear regressions. Yet, in weathered materials, especially in multifaced rocks, the rate of change of abrasion loss of weight increase more quickly than the decrease of dry density and the ultrasonic velocity. In case that tests cover a big range of values, from sound to weathered specimens, the existing relationship could be expressed better by exponential regressions.

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