ULTRASONIC VELOCITIES IN ROCKS: SOME SPECIAL FEATURES OF INDIAN GRANITES

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1. INTRODUCTION

DETERMINATION of ultrasonic velocities in rocks and their relation to certain geological features has been a subject of interest to geophysicists in recent years. The author has been engaged in measuring longitudinal and torsional velocities in several igneous, sedimentary and metamorphic Indian rocks. Experimental results so far obtained show that longitudinal velocities in most rocks lie in the region of 6000 m./sec. while the torsional ones are in the region of 3000 m./sec. Different rock specimens belonging to the same type but taken from different localities have been examined so as to ensure the representative character and accuracy of the velocities. Some, where they seem out of the way, have been verified by the author using different methods such as Wedge method (Bhagavantam and Bhimasenachar, 1944), reflection technique (Krishnamurthi and Balakrishna, 1953), and pulse technique (Pellam and Galt, 1956). The values in the case of Indian rocks are further compared with those obtained by Birch (1943), Hughes and Jones (1950) and Kubotera (1954) working on rocks of other countries. Out of all the Indian rocks, granites stand out prominently and show some special features in that they exhibit high ultrasonic velocities at room temperature and pressure in comparison with granites from other countries. In this paper an attempt is made to examine the behaviour of Indian granites in detail.

2. RESULTS AND DISCUSSION

The ultrasonic velocities in some Indian granites as determined by the total internal reflection method described by Krishnamurthi and Balakrishna (1953) are given in Table I. V_l (longitudinal) and V_t (torsional) velocities are in m./sec. and correspond to atmospheric pressure.

Young's modulus (Y), rigidity modulus (n) in units of 10^{11} dynes/cm.^{2} and the Poisson's ratio σ have also been tabulated in Table I.

TABLE I

Ultrasonic velocities in Indian granites

S. No.	Locality	Density gm./c.c.	V_l	V_t	Y	n	σ
1	Hyderabad ..	2·80	7157	2730	4·52	1·57	0·44
2	Hyderabad ..	2·68	6395	3362	7·93	3·03	0·31
3	Rajasthan ..	2·75	6085	3055	6·83	2·56	0·33
4	Errimpura ..	2·63	6134	3575	8·32	3·36	0·24
5	Errimpura ..	2·70	6236	2950	6·37	2·35	0·35
6	Jubbalpore ..	2·67	6250	3408	8·00	3·10	0·29
7	Jaggayapet ..	2·70	7460	3104	7·26	2·60	0·39
8	Jaggayapet ..	2·68	6870	3472	8·58	3·23	0·33
9	Podili ..	2·64	6420	3075	6·74	2·49	0·35
10	Podili ..	2·60	6080	3050	6·81	2·52	0·33
11	Podili ..	2·69	6674	2712	5·54	1·97	0·40
12	Vinukonda ..	2·60	6114	3020	6·63	2·46	0·34
13	Bundelkhand	2·65	5964	2852	6·54	2·42	0·35
14	Ranchi ..	2·62	6200	2952	6·17	2·28	0·35
15	Nagpur ..	2·58	6540	3150	6·93	2·56	0·34
16	Bihar ..	2·60	6160	2754	5·42	1·97	0·37

Table II gives the ultrasonic velocities in some American and Canadian granites as determined by Birch and his associates and by the author, using pulse technique. The figures given (V) are in km./sec. and correspond to atmospheric pressure.

The results of Tables I and II show that Indian granites exhibit high values even at normal pressures. This appears to be a special feature of theirs.

An attempt has been made in Table III to collect ample experimental data relating to granites to show that there are noteworthy discrepancies between results obtained by different methods. The values run over a wide range. Longitudinal velocity (V_l) is in m./sec. and Young's modulus (Y) is in units of 10^{11} dynes/cm.^{2}

TABLE II

Ultrasonic velocities in some American and Canadian granites

S. No.	Locality	Density gm./c.c.	V
1	Rock Fort ..	2·62	5·0
2	Barrfield ..	2·67	5·7
3	Bare ..	2·66	5·1
4	Chemsford ..	2·63	4·2
5	Engleheart ..	2·68	6·1
6	Sacredheart ..	2·66	5·9
7	Quincy ..	2·62	5·0
8	Latchford ..	2·68	5·7
9	Canada ..	2·72	6·1
10	Canada ..	2·64	6·5
11	Canada ..	2·65	6·5

It can be seen from Table III that ultrasonic velocities in granite depend on the method employed and consequently to some extent on the size and shape of the sample used. For instance Bacher's, Schafer's and Balakrishna's results in Table III show an agreement, presumably because they use high frequency methods and the sample is of the same size in all cases. Birch's results however show a marked difference because he uses long cylinders and also a low frequency method. Further it should be noted here that his values are not directly measured but they are obtained from the usual formulæ on the assumption that rocks are homogeneous and isotropic. He has computed Young's modulus, Posisson's ratio and the velocity of longitudinal waves in an infinite medium, in terms of the measured rigidity and compressibility. Results of Hughes appear to be a compromise between the two in that he uses fairly small cylinders and employs a high frequency ultrasonic pulse method, where the liquid does not come into contact with the rock. From Table III it can be concluded that velocities in rocks usually are higher than most other solids and that these velocities depend on the petrogenitic history of the rock, on the method which is employed and consequently on the size and shape of the sample. They also show some dependence on the density of the rock.

TABLE III

Comparison of ultrasonic velocities in granites

Author	Method	Locality	Shape	V_l	Y
Adams and Coker	Static	American	Large cylinder	..	4·1–6·3
Nagaoka	Flexural	Japan	,,	..	1·1–4·2
Bach	..	German	,,	..	2·4
Zisman	Ide's method	American	,,	5700	2·7–5·96
Leet	Seismic	American	Earth's crust	4500–5700	..
Bacher	Bez Bardili	German	Wedge shape	6500	..
Birch and Bancroft	Dynamic L.F.	American	Large cylinder	5200	2·7–5·7
Ide	Dynamic L.F.	American	Large cylinder	..	3·7–4·7
Schafer	Bar-Walti	German	Plate	5750	..
Muller	Spark photography	German	Small cylinder	..	5·7
Balakrishna	Wedge method	Indian	Plate	6326	4·2
Balakrishna	Pulse method	Indian	Plate	6400	3·7–4·52
Balakrishna	Balamuth and Rose	Indian	Small cylinders	6020	..
Hughes and Jones	Pulse method in solids	Texas	Rods	6050	..
Hughes and Cross	Pulse method in solids	Texas	Rods	5811	..
Kubotera	Ultrasonic pulses	Japan	Rods	4090–5890	..

Another aspect of study in granites relates to the grain size. In earlier publications by the author (1954), it has been shown that there is a difference of transmission of sound through different rocks and that this difference is intimately connected with granular structure or grain size. It was also shown that in coarse-grained rocks, the velocities are low and in fine-grained rocks, they are high. Both longitudinal (V_l) and torsional (V_t) velocities in m./sec. together with the density (gm./c.c.) and average grain size (mm.) for three typical granites are determined in this investigation and tabulated in Table IV.

TABLE IV

Velocities in granites versus *grain size*

S. No.	Locality	Density gm./c.c.	Grain size mm.	V_l	V_t
1	Jaggayapeta ..	2·68	0·4	6870	3472
2	Hyderabad ..	2·70	0·6	6375	3362
3	Rajasthan ..	2·75	1·5	6085	3055

From the above results, which are obtained by the same high frequency method for same types of rocks but from different localities, it can again be concluded that transmission of sound through granitic rocks is closely related to their granular structure, specially grain size. An important observation made here is that both the velocities (V_l and V_t) decrease with increasing grain size. It has also been noticed that absorption increases as grain size increases.

Indian granites have further been subjected to high pressures and the velocities in km./sec. at corresponding pressures are given in Table V. This work has been carried out by the author in Dunbar Laboratories using the pulse technique. Results relating to three samples of American granites are also included in the table.

Table V clearly shows that Indian granites at low pressures exhibit comparatively high values of velocities, and consequently a relatively small rise at high pressures (10,000 bars). A plot of longitudinal velocity *versus* hydrostatic pressure on the sample has the characteristic that the velocity increases rapidly at low pressures and only slowly at higher pressures (Fig. 1). This effect is more pronounced in American granites than in Indian granites. The peculiar behaviour of Indian granites, when compared with American granites, is to be attributed to their compactness, old age and their different petrogenitic history.

TABLE V

Variation of ultrasonic velocities with pressure in granites

S. No.	Locality		Density gm./c.c.	V_l P (0)	V_l P (10,000)
1	Indian	..	2·66	6·15	6·66
2	Indian	..	2·65	6·32	6·63
3	Indian	..	2·68	6·10	6·61
4	Chemsford	..	2·63	4·21	6·35
5	Rock Port	..	2·62	5·00	6·51
6	Barre	..	2·65	5·10	6·39

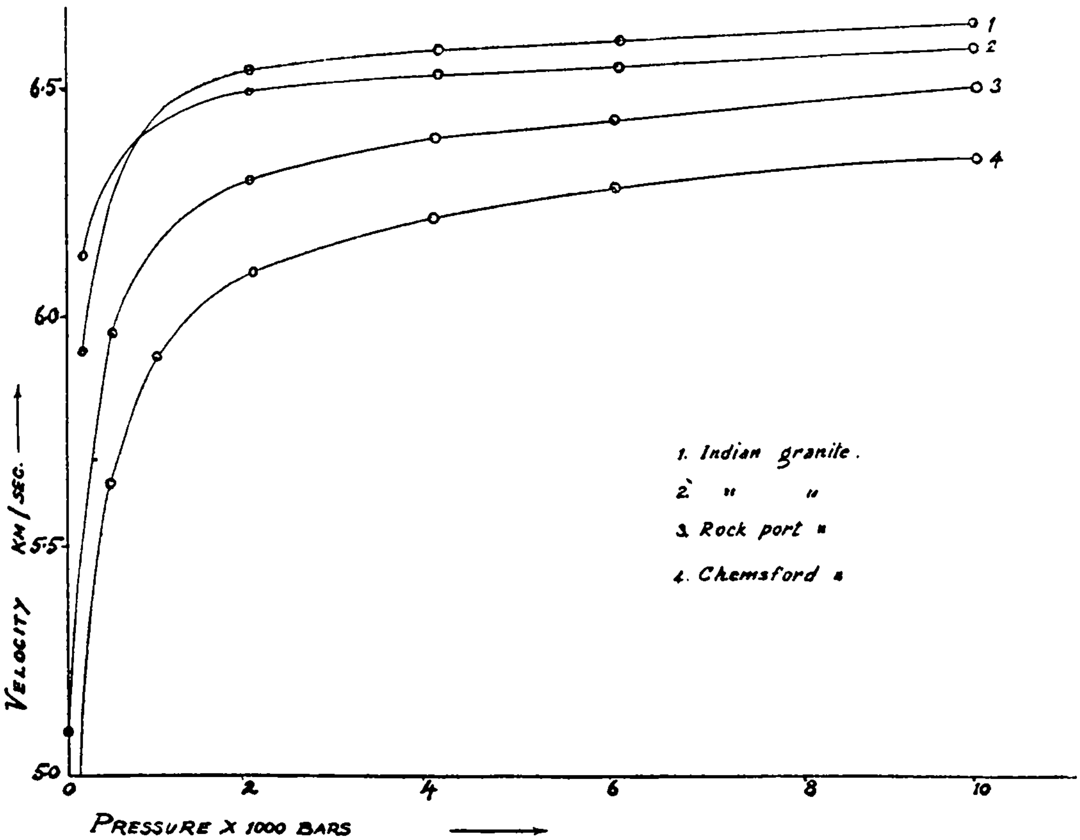

FIG. 1. Ultrasonic velocities in granites at different pressures.

3. Summary and Conclusions

It is now established that the sound velocity in most Indian granites is of the order of 6·2 km./sec. This relatively high velocity, when compared to granites from other countries at atmospheric conditions of pressure and temperature, indicates more compactness due probably to older age. Transmission of sound also depends mainly upon the granular texture. A plot of longitudinal velocity in rocks *versus* hydrostatic pressure on the sample shows that the velocity increases rapidly with pressure at lower values and then slowly with pressure in the higher ranges.

References

1. Balakrishna, S. .. *Proc. Ind. Acad. Sci.*, 1954, **41 A,** 12.
2. Bhagavantam S. and Bhimasenachar *Ibid.*, 1944, **20 A,** 298.
3. Birch, F. .. *Bull. Geo. Soc. Amer.*, 1943, **54,** 263.
4. Hughes, D. S. and Jones, H. J. *Ibid.*, 1950, **61,** 483.
5. Krishnamurthi, M. and Balakrishna, S. *Proc. Ind. Acad. Sci.*, 1953, **38 A,** 495.
6. Kubotera, A. .. *Jour. Phys. Earth*, 1954, **2,** 33.
7. Pellam, J. R. and Galt, J. K. .. *Jour. Chem. Phys.*, 1946, **14,** 608.