A NOTE ON SEISMIC VELOCITIES OF ROCK FORMATIONS ON BORNHOLM

P. VALLABH SHARMA

SHARMA, P. V.: A note on seismic velocities of rock formations on Bornholm. *Bull. geol. Soc. Denmark,* Vol. 23, pp. 191–196. Copenhagen, December 2nd 1974.

Seismic velocity data obtained from refraction shootings of 72 profiles on various rock formations on the island of Bornholm are listed. The correlation of seismic velocities with formations has been possible for certain rock types that show discrete velocity ranges. Significant velocity contrasts between some specific formations suggest the potentiality of the seismic refraction method as a tool for structural investigations on the southern part of the island.

P. Vallabh Sharma, Laboratory for Applied Geophysics, Institute of Geology, Østervoldgade 5–7, DK–1350 Copenhagen K, Denmark.
December 14th, 1973.

The island of Bornholm is a fault-bounded structure (Grönwall & Milthers 1916); the northern part consists of Precambrian granites and gneisses exposed on surface at various places whereas the southern part has an extensive cover of Palaeozoic and Mesozoic sediments. The present distribution of the different rock types is strongly controlled by numerous faults. Faulting took place from Precambrian to Tertiary time. The geology of southern Bornholm (fig. 1) is very complicated because of a great number of faults. Gravity and magnetic surveys (Saxov, 1945; Münther, 1973) have been carried out to unravel the deeper structure, but because of insufficient density and susceptibility contrasts in the Palaeozoic and Mesozoic formations the data have been of very limited use.

In recent years seismic refraction work has been carried out on Bornholm as an aid to geological mapping. As regards information about seismic velocities, Bornholm is a virgin area. Correlation of seismic velocities with formations in a new area is imperative for application and interpretation of seismic data. With this objective in view, velocity shootings were made on outcrops of various rock types on Bornholm. The localities of velocity shootings are shown in fig. 2.

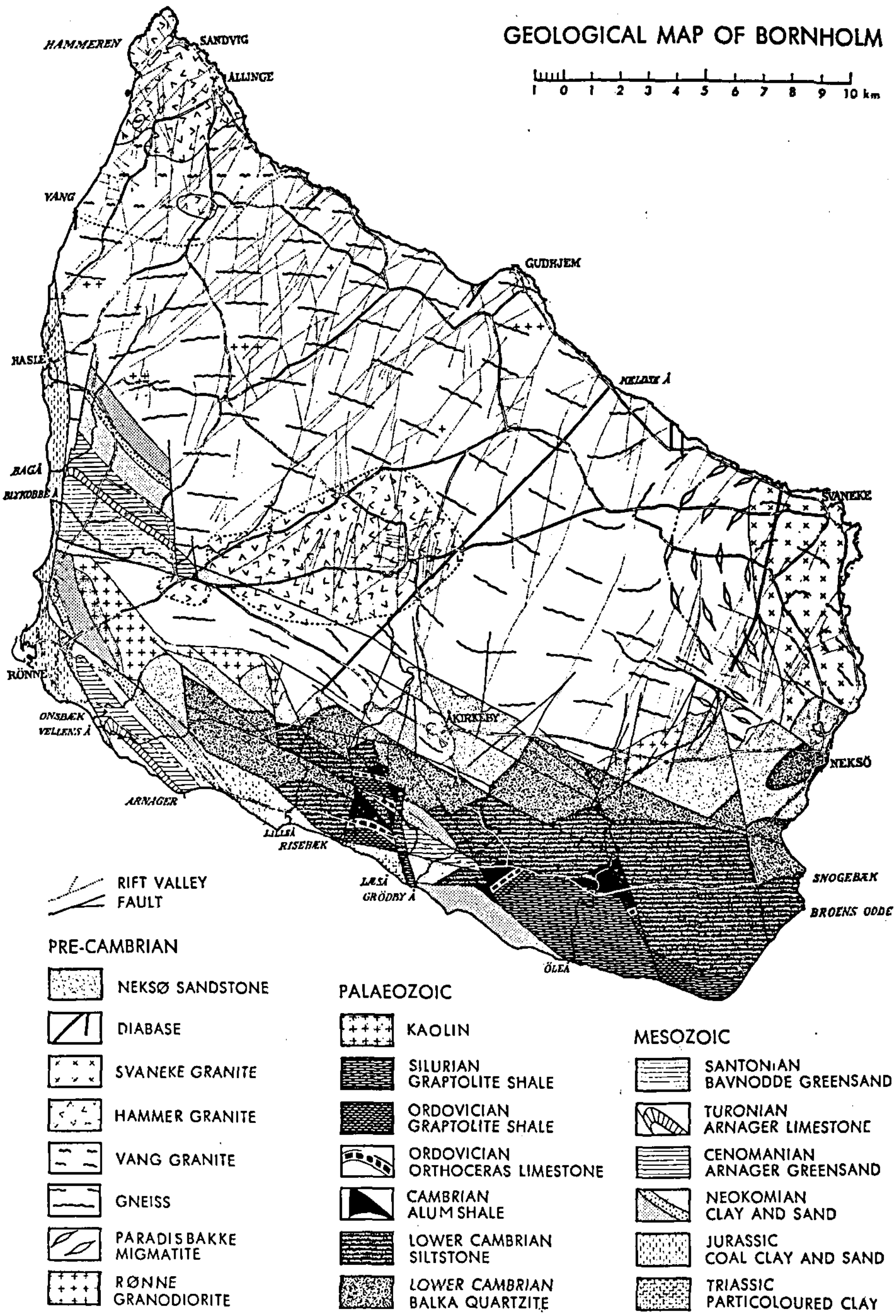

Fig. 1. Geological map of Bornholm (based on H. Gry, H. Micheelsen and others and after Rasmussen, 1966).

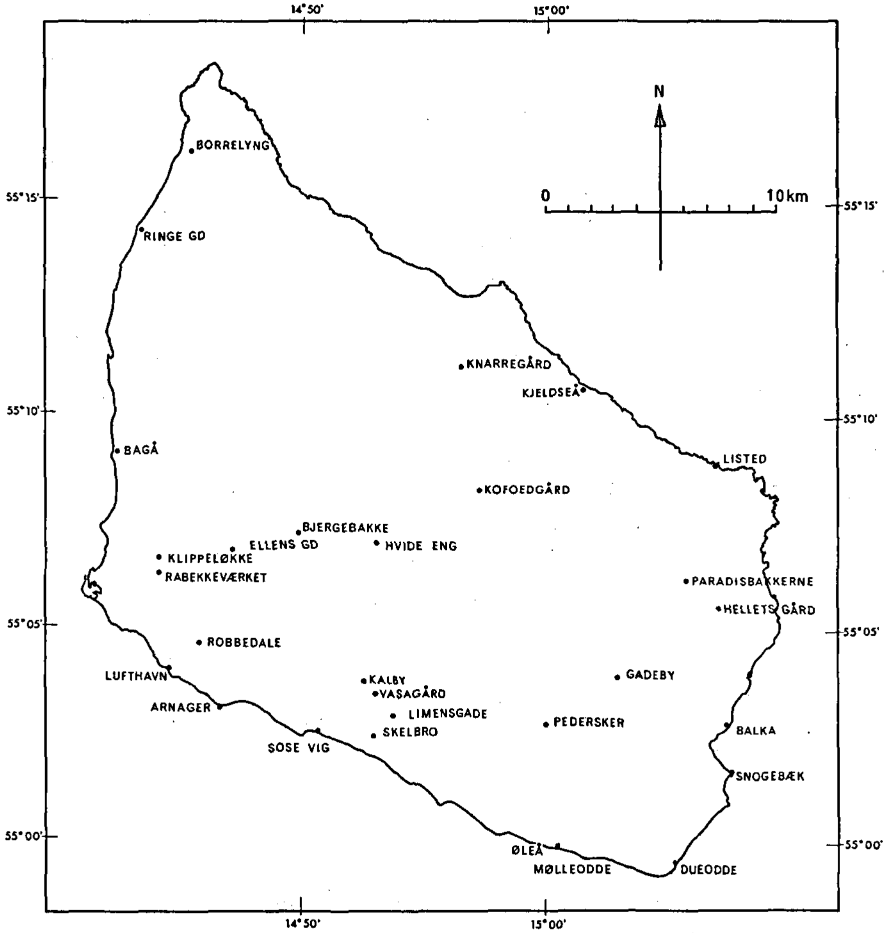

Fig. 2. The localities of velocity shootings on Bornholm.

Method of "outcrop shooting"

The simplest way of measuring the velocity of a particular rock formation is to set up a spread of geophones on its outcrop, fire a shot, and time the passage of direct waves that reach the geophones. Since "outcrops" are nearly always covered by Quaternary deposits it is in fact the refracted wave travelling below the Quaternary cover that is timed as "first arrival" on the seismogram. Because of the varying thickness of the Quaternary cover, it is necessary to "reverse" the profile, i. e. to shoot on both ends of a geophone spread and average the velocities by the "plus – minus" method.

The geophone spread used for most of the velocity profiles in Bornholm was 110 m with 10 m spacing and wherever possible geophone lines were run both parallel and normal to the strike of rock formation. For firing a shot, the normal practice was to place the explosive charge of 200 to 500 g in a polythene bag filled with water in a hand-dug hole about half a metre deep. Sometimes it was necessary to use a greater amount of explosive (up to 1 kg), particularly on outcrops of unconsolidated formations such as loose sand and gravel.

Correlation of velocities with formations

Table 1 shows the range of velocities obtained for the various rock formations on Bornholm. Mean values at localities are given without any attempt to express the scatter of values by an error function. This is because standard deviations have little significance when variations of velocity from record to record are much greater.

For a majority of the Mesozoic formations the velocity values lie between 1600–1800 m/s, the only exceptions being the Arnager limestone (2200 m/s) and the Robbedale gravel formation (800 m/s). The marked velocity contrasts shown by these two formations should permit their identification (at depth) from refraction velocities.

Amongst the Palaeozoic formations, alum shales (2600 m/s) show considerably low velocity compared to the green siltstone (3300–3650 m/s) and the Ordovician limestone (3200–3550 m/s). As to the Cambrian sandstones there is an overlap of velocity ranges for the green siltstone (3300–3650 m/s), Balka sandstone (3400–3700 m/s) and Nexø sandstone (3200–3550 m/s), which makes it difficult to differentiate one from another by seismic velocity alone. These formations are much alike also in their density values (Saxov & Abrahamsen, 1964). On the other hand, electrical resistivity and magnetic susceptibility contrasts between them are quite significant.

In the Precambrian formations, Svaneke granites characterize themselves by relatively low velocities (4650–4900 m/s) in comparison with migmatites (~ 5500 m/s) and gneisses (~ 5700 m/s). Also, Almindingen granites (4700–5000 m/s) have somewhat lower velocities than the other groups of granites (e.g. Vang granite, Hammer granite). Rønne granites show a considerable spread in velocities, with a mean value of about 5150 m/s which is rather low in relation to their high density of 2.75 g/cm^3 (Saxov & Abrahamsen, 1964).

Summary and conclusions

The results of velocity determinations show a scatter of 10 to 15 % in velocity values of the same formation at different localities. No systematic difference was observed between velocities measured parallel and normal to the strike direction of a rock formation. In some cases, where the velocity spread within a formation is of the same order as the velocity contrasts relative to other formations, it is not possible to assign discrete velocity ranges to these formations. On the other hand, the observed velocity contrasts between a number of specific formations, e.g. between Arnager limestone and green sand, between alum shales and green siltstone, between the Ordovician limestone and alum shales, between the Nexø sandstone and granites/gneisses do suggest the potential applicability of the refraction method to local structural problems in southern Bornholm.

Acknowledgements. I would like to thank all the student participants in the summer field courses from 1969 to 1972 during which the velocity measurements were carried out. Steffen Lauge Petersen and Christian Mohr provided valuable field assistance. I am deeply indebted to the late Prof. Henry Jensen of the Geophysics Institute for the loan of the ABEM refraction unit.

Dansk sammendrag

Seismiske hastighedsdata fra 72 refraktionsprofiler på forskellige bjergarter på Bornholm presenteres. Det har været muligt at placere nogle af bjergarterne i bestemte hastighedsgrupper. Betydelige hastighedsforskelle, som er påvist mellem nogle af bjergarterne, antyder at den refraktionsseismiske metode kan benyttes til strukturelle undersøgelser på den sydlige del af Bornholm.

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Table 1. Seismic velocities (V_P) of rock formations on Bornholm.

Geological age	Rock type	Locality	No. of reversed profiles	Mean velocity (m/s)
Cretaceous	Bavnodde Greensand	Lufthavnen	2	1750
	Arnager Limestone	Arnager	3	2220
	Arnager Greensand	Arnager	2	1780
Jurassic	Robbedale sand and gravel	Robbedale	2	820
	Coal carrying sand	Bagå	2	1800
	Coal carrying sand	Sose Vig	2	1860
	Kaolin	Rabekkeværket	2	1600
Silurian	Graptolite shales	Øleå	2	2880
Ordovician	Limestone	Limensgade	2	3160
	Limestone	Skelbro	3	3520
Cambrian	Alum shales	Vasagård	2	2540
	Alum shales	Limensgade	2	2600
	Green siltstone	Snogebæk	2	3650
	Green siltstone	Dueodde	1	3440
	Green siltstone	Kalby	2	3330
	Balka sandstone	Balka strand	3	3480
	Balka sandstone	Snogebæk	2	3600
	Balka sandstone	Pedersker	3	3720
	Nexø sandstone	Balka strand	3	3260
	Nexø sandstone	*Gadeby quarry*	2	3550
Precambrian	Diabase dykes	Listed	2	5860
	Diabase dykes	Kjeldseå	2	6270
	Diabase dykes	Kofoedgård	1	6150
	Svaneke granite	Helletsgård	2	4860
	Svaneke granite	Listed	2	4650
	Hammer granite	Borrelyng	3	5400
	Vang granite	Ringegade	2	5320
	Almindingen granite	Bjergbakke	1	4720
	Almindingen granite	Hvide Eng	2	4830
	Almindingen granite	Ellensgade	1	5000
	Rønne granite	Klippeløkke	2	4940
	Rønne granite	Rabekkeværket	3	5400
	Migmatite	Paradisbakkerne	3	5540
	Grey gneiss	Knarregård	2	5700