18. COMPRESSIONAL WAVE VELOCITIES IN SELECTED SAMPLES OF GABBRO, SCHIST, LIMESTONE, ANHYDRITE, GYPSUM AND HALITE

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INTRODUCTION

The velocity of propagation of compressional waves was investigated in samples of gabbro, limestone, schist, anhydrite, gypsum, and halite recovered during Leg 13 of the Deep Sea Drilling Project. Individual measurements of selected specimens were first conducted at atmospheric pressure and then at intervals of higher confining pressure up to 7 kilobars. The data presented here may provide useful criteria for correlation of the sediment and rock units cored at the various drill sites to levels in the seismic reflection, oblique reflection, and refraction profiles obtained from the Mediterranean basins.

PROCEDURES

Specimens one half inch in diameter were cut from the drill cores in directions parallel to and perpendicular to the drilling axis, thus providing information concerning velocity anisotropy that may be present. The ends of the specimen were trimmed flat to produce surfaces that were parallel to within 0.002 cm. The bulk density of each specimen was calculated on the basis of the dimensional measurements and its mass. Unless otherwise indicated, the error of the density measurements is ±1 per cent. Prior to the measurement of the compressional-wave velocities, the specimens were jacketed with 2-mil-thick copper foil. The purpose of jacketing the specimen was to prevent the pressurizing fluid from penetrating pores or cracks present in the specimen in order that the contribution to the change in velocity as cracks and pores close under increasing pressure could be estimated. Specimens were measured in the "as received" condition and were neither dried nor saturated prior to the velocity measurements.

Measurements were performed using the modified pulse transmission method described in Volume XI of the *Initial Reports of the Deep Sea Drilling Project* (Schreiber *et al.*, 1972). The inherent precision of the method is at least 0.1 per cent; however, this precision is reduced to about 1 per cent when rock specimens are used because of an hysteresis that usually occurs between the increasing and decreasing pressure runs. This hysteresis arises from anelastic changes that occur within the specimen, and these are attributed to changes in the pore and crack geometry that arises during application of pressure. The data reported in Table 1 are smoothed averages between the up- and down-pressure runs.

DISCUSSION OF THE RESULTS

Gabbro

Metagabbros were recovered from the inferred basement at Gorringe Bank (Site 120) in the eastern North Atlantic (see Chapter 2 of this volume). The samples investigated were cataclastized and of the greenschist facies. Five specimens were measured at two sample intervals in Core 8. The results exhibit a wide range of velocities varying from 4.99 to 6.28 km/sec at 0.5 kilobar confining pressure up to 5.76 to 6.8 km/sec at 7 kilobars. More measurements are needed before it will be possible to determine whether or not the velocity anistropy observed in these five samples is due to preferred orientation. The observed velocity differences, however, can be a function of either preferred grain orientation developed during metamorphism and/or cataclasis, or the preferred alignment of microfractures. The results for metagabbros reported here fall within the range observed by Fox *et al.* (1971) for metamorphosed gabbro dredged from fracture-zone escarpments near the crest of the mid-oceanic ridge.

Schist

Low-grade metamorphic siltstones and sandstones were recovered from the western slope of Sardinia at Sites 133 and 134 (see Chapters 14 and 15 of this volume). These rocks have a penetrative fabric consisting of strained quartz with a secondary matrix of sericite (see Chapter 26 of this volume). A representative sample of the schist suite from Core 3 of Site 133 shows a slight apparent anisotropy with higher velocities perpendicular to the penetrative fabric. The values, at 0.5 kilobar confining pressure, of 5.12 to 5.58 km/sec correspond well with a refracted velocity of 5.4 km/sec for a shallow basement layer observed by Fahlquist and Hersey (1968) in Profile 3 beneath the northwestern slope of the Corsica-Sardinia microcontinent (Figure 1). Furthermore, values of 5.43 to 5.73 km/sec at 1.5 kilobars confining pressure (corresponding to a burial depth of 8 km) bracket the measured refracted velocity of 5.7 km/sec for the possible seaward extension of the microcontinent observed dipping westward beneath the Balearic Abyssal Plain in Profile 2.

If this correlation is valid, we deduce that at least the easternmost edge of the present abyssal plain is floored by foundered fragments of Sardinia and Corsica, an interpretation compatible with the drilling results of Holes 134A, B, C, D, and E on the plain.

TABLE 1
Summary of Compressional Wave Velocities for Rocks Recovered During DSDP Leg 13[a]

Sample No.	Rock Type	Depth in Core (cm)	Depth Below Sea Floor (m)	ρ gm/cm^3	Pressure Kb 0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0
120-8-1A	Meta-gabbro greenschist facies	46-50	252	2.72	6.18	6.36	6.50	6.58	6.62	6.67	6.70	6.71	6.72	6.73
120-8-1B	Meta-gabbro greenschist facies	46-50	252	2.69	4.99	5.24	5.35	5.43	5.50	5.54	5.61	5.68	5.74	5.80
120-8-1C	Meta-gabbro greenschist facies	46-50	252	2.73	5.68	5.94	6.06	6.14	6.19	6.23	6.30	6.36	6.41	6.44
120-8-1A	Meta-gabbro greenschist facies	86-90	252	2.54[b]	4.90	5.14	5.28	5.36	5.42	5.46	5.52	5.59	5.65	5.69
120-8-1B	Meta-gabbro greenschist facies	86-90	252	2.67	5.04	5.14	5.22	5.29	5.35	5.41	5.52	5.62	5.69	5.76
124-10-1A	Massive anhydrite	72-75	401	2.56	4.29	4.39	4.48	4.55	4.60	4.65	4.74	4.83	4.90	4.95
124-10-1B	Massive anhydrite	72-75	401	2.52	4.66	4.74	4.80	4.86	4.91	4.96	5.04	5.11	5.16	5.21
124-10-2A	Massive anhydrite	114-124	403	2.63	4.79	4.88	4.91	4.94	4.96	4.97	4.99	5.00	5.01	5.02
124-10-2B	Massive anhydrite	114-124	403	2.63	4.87	4.92	4.97	5.00	5.03	5.05	5.08	5.11	5.14	5.17
124-11-2A	Nodular anhydrite	114-124	407	2.74	4.76	4.86	4.93	4.98	5.03	5.08	5.16	5.23	5.28	5.33
124-11-2B	Nodular anhydrite	114-124	407	2.76	4.85	4.94	5.00	5.06	5.11	5.15	5.23	5.30	5.37	5.45
127-18-1A	Dolomitized micritic limestone	61-68	436	2.71	6.46	6.50	6.52	6.54	6.55	6.56	6.59	6.60	6.61	6.61
127-18-1B	Dolomitized micritic limestone	61-68	436	2.75	6.54	6.58	6.60	6.63	6.65	6.67	6.69	6.70	6.71	6.71
127-19-1A	Brecciated dolomitized limestone	63-76	437	2.82	6.65	6.74	6.80	6.85	6.89	6.91	6.95	6.93	7.01	7.03
127-19-1B	Brecciated dolomitized limestone	63-76	437	2.79	6.81	6.89	6.93	6.96	6.96	6.97	6.98	6.99	7.00	7.01
132-27-2A	Gypsum	0-5	222	2.27	4.91	4.94	4.96	4.99	5.01	5.03	5.05	5.07	5.09	5.10
132-27-2B	Gypsum	0-5	222	2.30	4.85	4.96	5.04	5.09	5.13	5.17	5.23	5.28	5.31	5.33
133-3-1A	Schist-metasand-stone series	142-145	68	2.70	5.58	5.67	5.73	5.77	5.81	5.84	5.89	5.93	5.96	5.99
133-3-1B	Schist-metasand-stone series	142-145	68	2.68	5.13	5.31	5.43	5.51	5.58	5.64	5.71	5.76	5.79	5.81
134-10-2A	Halite	95-108	362	2.16	4.05	4.10	4.14	4.17	4.20	4.22	4.26	4.28	4.31	4.33
134-10-2B	Halite	95-108	362	2.15	3.54	4.15	4.24	4.27	4.31	4.33	4.36	4.39	4.41	4.43

[a]The specimens are numbered in the following way. The first, second, and third parts are the DSDP site, core and section identification number. The letter A denotes a specimen whose cylindrical axis is parallel to the drilling direction; B and C denote samples taken at right angles to each other with the cylindrical axis of these specimens being perpendicular to the drilling direction.

[b]Denotes ±2 per cent error, all other samples ±1 per cent.

Limestone

Lithified limestone was recovered at Site 127 from the inner wall of the Hellenic Trench in the Ionian Basin of the eastern Mediterranean. Four samples from two characteristic lithologic units, dolomitized micritic limestone (Core 18) and brecciated dolomitized limestone (Core 19), were found to yield very high compressional velocities. The density of these limestones is greater than that of single crystal calcite; this reflects the effect of dolomitization. Also, the presence of dolomite contributes to the high measured compressional-wave velocities. The results reported here for limestone are higher than many previously reported measurements, but lie within the range of values tabulated in Anderson and Leibermann (1968). When velocities in the 6.6 to 6.8 km/sec range are recorded for a velocity horizon in an ocean basin by seismic refraction methods, it is assumed that the horizon is basement and is composed of igneous or metamorphic rock. It is interesting to note that the dolomitized limestone recovered at Site 127 has velocity characteristics in this range. We do not mean to imply that oceanic basement is limestone, but rather to emphasize the possible range of interpretation of seismic data.

Evaporite Suite

Representative samples were investigated from the suite of Upper Miocene evaporite rocks recovered from the western Mediterranean. The anhydrite samples from Cores 10 to 11 at Site 124 on the Balearic Rise yielded velocities that are lower (4.30 to 4.88 km/sec at 0.5 kilobars; 4.95 to 5.55 km/sec at 7 kilobars) than that measured for the one specimen of pure anhydrite reported in Anderson and Liebermann (1968). The previously published values range from 4.8 km/sec at 1 atmosphere to 6.19 km/sec at 6 kilobars confining pressure.

A sample of massive, recrystallized gypsum (replacement after anhydrite) was investigated from Core 27 of Site 132 in the Tyrrhenian Basin. Velocity values of 4.89 to 4.91 km/sec at 0.5 kilobar and 5.10 to 5.34 km/sec at 7 kilobars fall within the same range as that of the anhydrite, which, if representative of the area in general, will make it difficult—if not impossible—to discriminate the different sulfate phases by reflection or refraction seismology. The reason the most dense anhydrite sample yielded a velocity much closer to that for gypsum than reported for anhydrite has not been determined. The low values for the anhydrite reported here may arise from its very fine aggregation of randomly oriented micron-size laths, the presence of hemi-hydrate, and possibly even some undehydrated gypsum, and its association with algal stromatolites (chicken-wire structure) rich in clay minerals (see Chapters 21 and 22, this volume).

The halite samples from Core 10 of Site 134, beneath the Balearic Abyssal Plain, exhibit a considerable velocity range (3.54 to 4.05 km/sec at 0.5 kilobar) at low pressure. measured values converge at higher confining pressures, suggesting that the observed deviations may arise principally from differences in the concentration of cracks

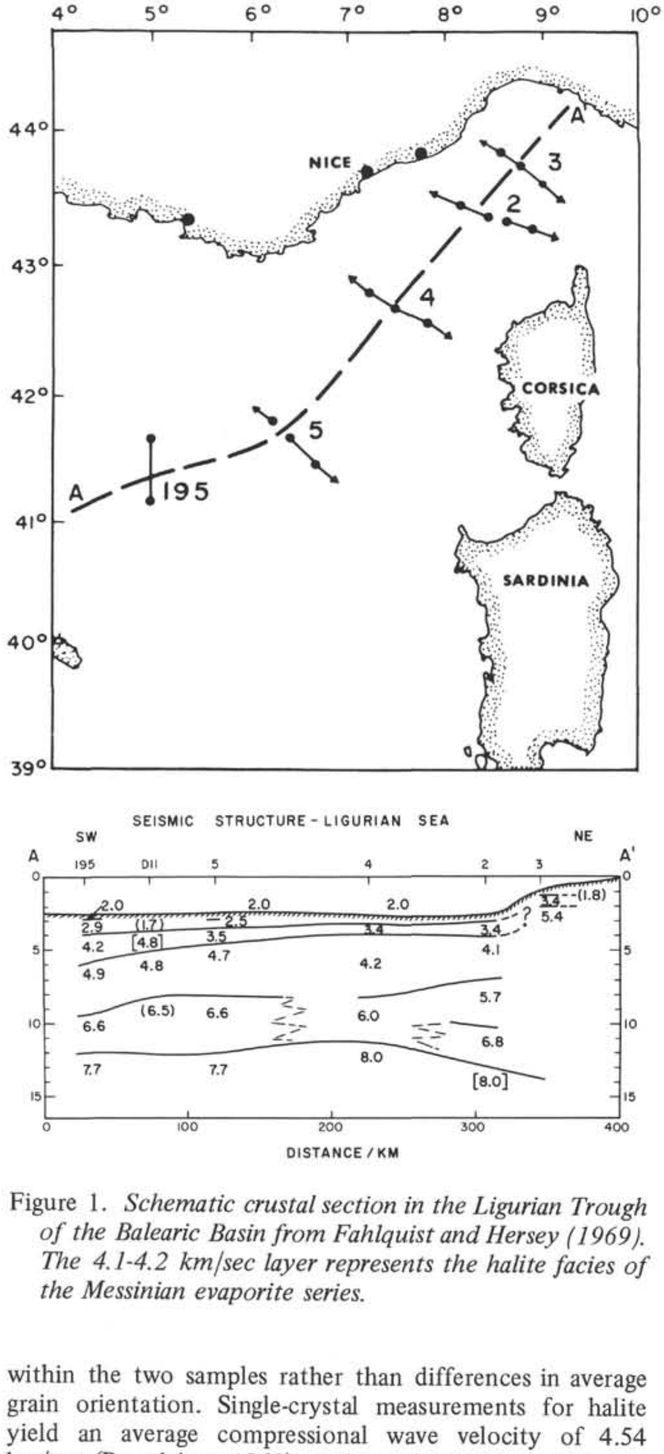

Figure 1. *Schematic crustal section in the Ligurian Trough of the Balearic Basin from Fahlquist and Hersey (1969). The 4.1-4.2 km/sec layer represents the halite facies of the Messinian evaporite series.*

within the two samples rather than differences in average grain orientation. Single-crystal measurements for halite yield an average compressional wave velocity of 4.54 km/sec (Papadakes, 1963), and we therefore consider our results to suggest that there is no strong orientation effect.

The measured velocities of 4.14 to 4.24 km/sec for halite at 1.5 kilobars correlate markedly with the narrow range of refracted wave velocities (4.08 to 4.26 km/sec) observed by Fahlquist and Hersey (1969) beneath the Balearic Abyssal Plain in the Ligurian Trough (Profiles 2, 4, and 195, Figure 1). It is noted that this axial zone of the trough contains the greatest concentration of diapirs (piercement domes) (Glangeaud *et al.*, 1966). Linear sedimentary ridges beneath the abyssal plain south of the Balearic Islands were noted by Ryan *et al.* (1971). Since the 4.08 to 4.26 km/sec seismic layer is observed 0.69 to 1.09 km beneath the sea floor at Profile 198 in this region of the basin, this seismic layer represents a logical westward continuation of the halite deposit. Consequently, we conclude that the buried anticlinal structures of the southern Balearic Abyssal Plain are salt ridges. Furthermore, we note that refracted arrivals, giving compressional wave velocities in the range of 4.08 to 4.26 km/sec, and thus assignable to halite, come from upper surfaces of seismic layers beneath the abyssal plain which range in depth from 3.41 to 4.98 km below present sea level (data from nine profiles of Fahlquist and Hersey, 1969). These seismic velocity data indicate that the halite phase of the evaporite suite is confined to the deepest parts of the basin floor and is not observed to transgress into shallower regions of the continental margins.

The compressional-wave-velocity characteristics presented here for the sulfate facies (anhydrite and gypsum) and the halite facies suggest that seismic refraction and reflection data could provide the basis for mapping the location and extent of these two components of the evaporite suite in the Mediterranean basins, thus providing a crude but useful estimate of the total volume of the evaporite suite.

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