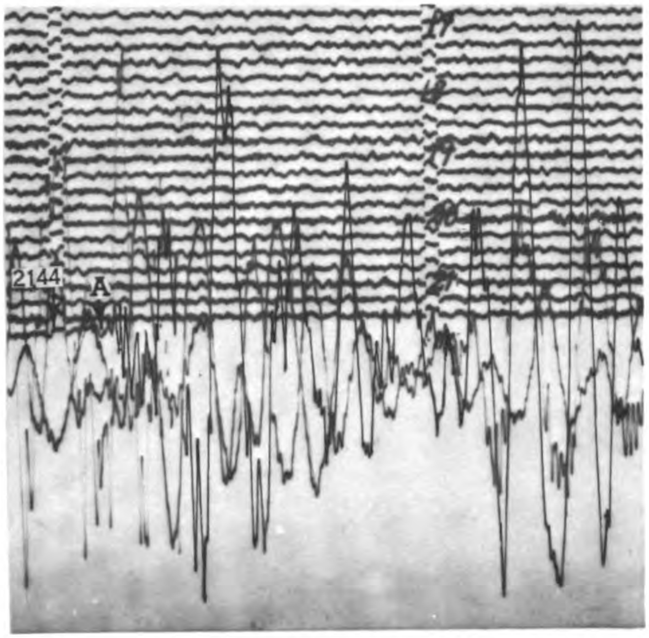

Fig. 8 A section of the short period seismogram from station ARE (Arequipa, Peru) registering the vertical motion from the seaquake experienced by the BELMONT; the regularly spaced lines, separated by 15 min., indicate normal background noise. The activity started at the station shortly after 2144 GMT (point "A")

nalysis of ship reports describing seaquakes, considered with respect to local geological conditions and available instrumental data, reveals several generalities that are in line with facts known about landquakes.

The principal seismic effect aboard ship is the jackhammering vibrations induced on the hull by the arrival of the P wave (primary wave, longitudinal). Upon entering the less dense water from the sedimentary covering on the ocean floor this compressional-type wave is bent by refraction and deflected almost vertically to the sea surface at 0.8 mi. per second. Frequently, the first P waves to arrive on the surface of the sea are not strong enough to be felt aboard ship and will pass into the atmosphere above the sea to create a sound wave. When the frequency of the sound wave is high enough to be audible a loud "booming" noise will immediately precede the actual vibrations. Sound is not heard in all earthquakes, and it is possible under certain conditions to have the sound without the vibrations.

The duration of the vibrations may vary from a fraction of a second to several minutes. Ship reports indicate a usual duration of between 15 and 60 sec. When the P wave arrives at the sea surface its period is short and amplitude very low. Normally, the amplitude is so small there is no indication of a disturbance in the appearance of the sea surface. Yet this wave front simultaneously striking the complete underwater portion of the hull produces enough energy to cause severe vibrations. Rarely have these vibrations damaged ships, but a report from a ship near 18°03'N., 103°19'W., on April 15, 1941, stated that earthquake vibrations caused "a large deckload of steel assembly, some pieces weighing 6 tons, to shift about 6 in. and to jump as much as 5 to 6 in. up and down from its blocks." Also on June 15, 1966, the MV NINGHAI at 10°35'S., 161°05'E., in the Solomon Islands, reported the following damage after being shaken repeatedly at various intervals for about 2 hr: "The cathode ray tube shattered. the capillary tube in the barometer (was) smashed, valves were shaken out of their sockets in the wireless transmitter the suspension wire on the gyro snapped and the azimuth mirror on the monkey island gyro repeater fell off. In addition we made some water in No. 3 double bottoms and after peak; also the main engine fuel line was broken and the sanitary tank on the monkey island was holed. No water was made after the tremors, which suggests that as the ship was being shaken water was entering these tanks through various rivets and seams which had started and opened, but only for the duration of these tremors. The masts whipped about a great deal, and the funnel rattled alarmingly."

Occasionally, there is a weaker but definitely distinguishable second set of vibrations closely following the original jolt. This is not a twin quake but the arrival of part of the energy from the slower S wave (secondary wave, transverse). When this shear wave strikes the density discontinuity at the ocean floor, part of the energy is reflected back into the earth and part of the energy is transformed into a compressional-type wave and deflected almost vertically into the less dense water. There is an energy loss in this transformation, but the arrival of the S wave under the hull is quite perceptible under proper conditions. If a vessel is in the immediate epicentral area of a shallow quake, the arrival of the second group will only tend to intensify the original vibrations and may not be detected. When the epicentral distance is too great the arrival of a weak second group may be imperceptible. However, there is a definite area between the two extremes in which the arrival of the S wave group is easily distinguishable.

The intensity of shipboard vibrations is determined by internal as well as external variables. Internal factors include the type and construction of the ship, the nature and amount of cargo on board - as well as the manner in which it is stowed - and under certain conditions, the position in which the cargo-handling gear or other heavy equipment is secured. Among the external variables the magnitude of the earthquake (determining the amount of energy released) and the depth of the original fracture (hypocenter) are very important. Frequently, the perpendicular distance to the fault along which the original fracture occurred may be more important than the epicentral distance. The earthquake energy tends to travel great distances down or parallel to the fault with little loss of intensity, but the perceptibility tends to fall off rather rapidly as the perpendicular distance from the fault increases. Although weather has no bearing on the origin of an earthquake, the effects (vibrations) on ship may be magnified by unfavorable weather conditions.

An excellent example of the varied manner in which individual ships, located at random about the epicenter of an earthquake are affected, is available from

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