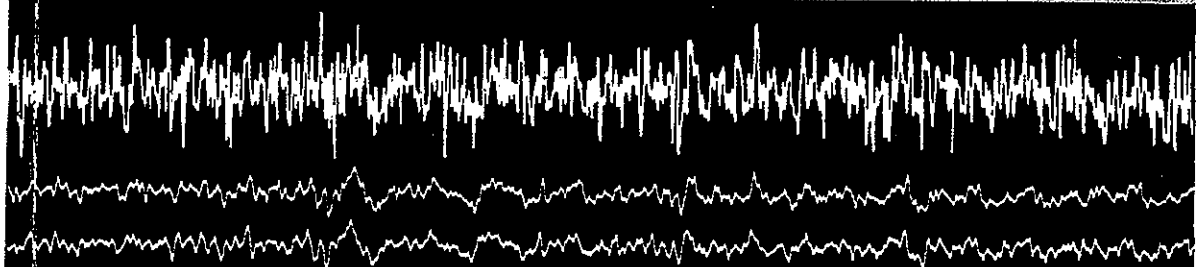


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NUMBER 7

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cally monitored by radio navigation so that shots (or "pops") can be fired at the desired locations.

Just as with land records, marine shot records also are recorded and displayed in time (Figure 7). Instead of traces showing stations versus time, they are referred to as *channels* versus time. The shot records in Figure 7 have the ship and energy-source position to the left of the streamer. Seismic events such as A arrive first at channels on the left which are nearest to the source, then spread to the right in a curved manner. Event B is the direct arrival. The area of a marine shot record of greatest interest to the geophysicist is windowed on the right-hand record. A comparison of the land shot record (Figure 5) with the marine records shows that the marine events appear more continuous across the record. Although some reflection events are visible on the land record, most of that record is obscured by surface-generated noise. The marine record—being relatively noise free—is said to have a high signal-to-noise ratio, while the land record has a low signal-to-noise ratio. Reasons for this are discussed in greater detail in Chapter 3.

Consider again the land and marine acquisition schemes (Figures 4 and 6). After each land shot, the line of receivers may be moved along to another appropriate location and the shot fired again. This is the so-called *roll-along method* of seismic recording, the parameters of the roll-along being governed by both the geology and how the data are to be processed. Alternatively, the geophones may be left in place while the shot position is moved several times. To record an extensive number of lines on land is clearly time consuming because of the need to reposition the geophones manually. In marine

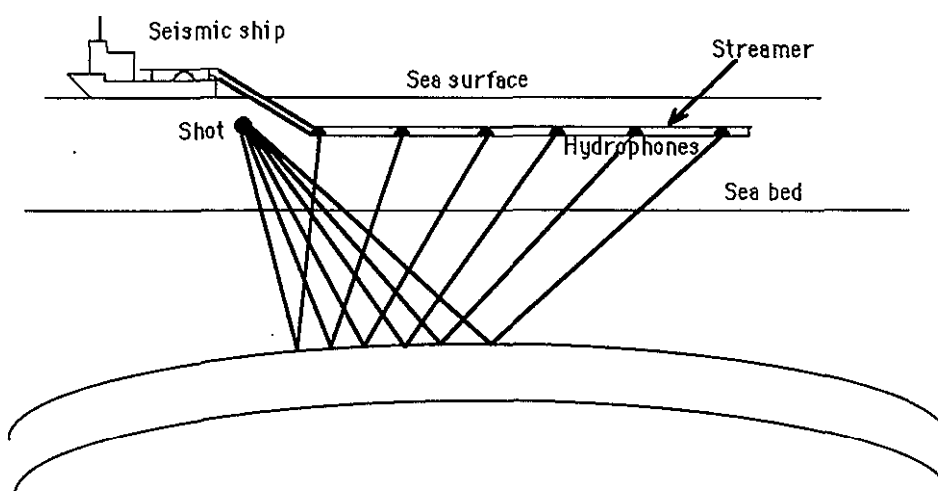


Fig. 6. Marine recording technique.

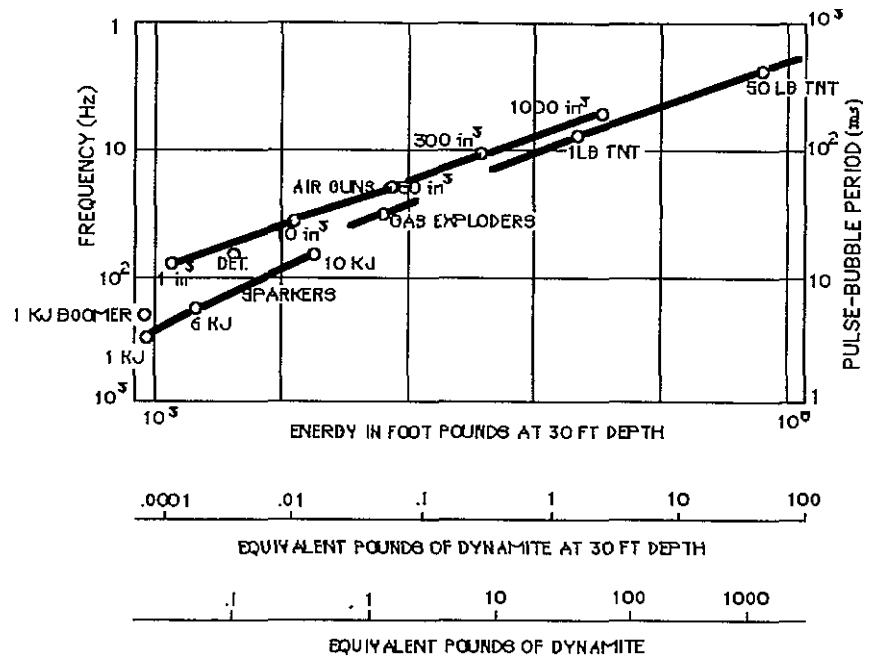


Fig. 114. The Rayleigh-Willis diagram relating pulse-bubble period to potential energy.

3.5 Source and Receiver Depth (Ghost Effect)

On land, the burial depth of a dynamite charge can affect the exploding wavefront's amplitude and shape. Tests have been conducted with charges loaded in clay, sand, water-filled holes and cemented holes over the years (e.g., McCready, 1940). The frequency spectrum may increase with depth but can be distorted by the surface ghost. Shallow charges often have poor amplitude and frequency content because of detonation within a porous weathering layer. Ideally, the charge should be placed beneath the weathering for improved statics corrections and superior signal-to-noise ratio, plus less surface noise.

The charge depth governs a phenomenon called *ghost interference*. As shown in Figure 115, a ghost is created by the downward reflection of the primary pressure pulse from the surface, the weathering layer, or both. A ghost has a polarity opposite to that of the primary.

If the ghost arrival time corresponds with a true reflection, the shot depth must be adjusted immediately. This tends to be more of a problem with land, where hole depth may be greater than 30 m (100 ft), than marine, where air-gun depth is generally 6–7.5 m (20–25 ft). Another problem, however, is not of

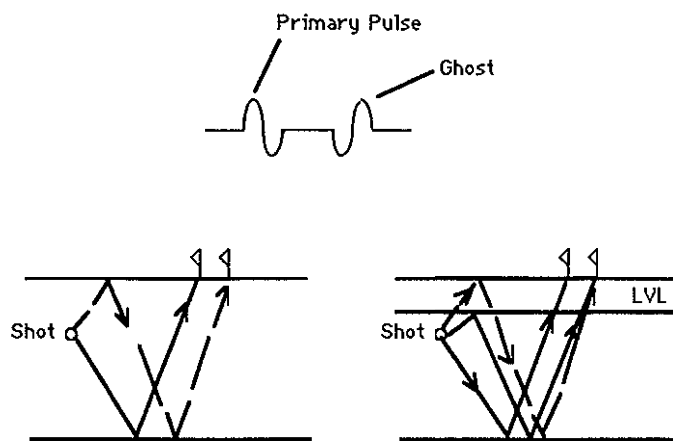


Fig. 115. Ghost generation.

the ghost interfering with a reflected event but the ghost actually causing notching of the frequency spectrum.

In Figure 116, the solid line represents a direct downgoing wave and the dashed line represents the wave reflected from the surface. The physics of sinusoidal wave propagation states that when two waves have the same wavelength, destructive interference (cancellation) occurs when they arrive exactly 180° out of phase. Because the reflection coefficient at the surface is negative, the downgoing reflected wave experiences a 180° phase shift relative to the direct wave. However, the reflected wave experiences a further phase shift because of the additional distance, $2d$, that it travels relative to the direct wave. If destructive interference is to occur, that distance must be an integral number of wavelengths. That is, destructive interference occurs when $2d = n\lambda$, where $n = 0, 1, 2, \dots$. Since $\lambda = V/f$, the notch frequencies where destructive interference is experienced are given by

$$f = \frac{nV}{2d}, \quad n = 0, 1, 2, \dots \quad (35)$$

For example, if $V = 1500$ m/s and $d = 6$ m, then source ghost-notch frequencies are at 0, 125, 250, ... Hz. Figure 117 shows field examples of the signature of an air-gun array as the array changes depth. PTP refers to the peak-to-peak strength, and the PBR refers to the primary-to-bubble ratio.

Figures 118 and 119 display normalized versions of the normalized amplitude spectra for source and receiver arrays as a function of source and receiver depths. Figure 118 maintains the source array constant at 5 m and

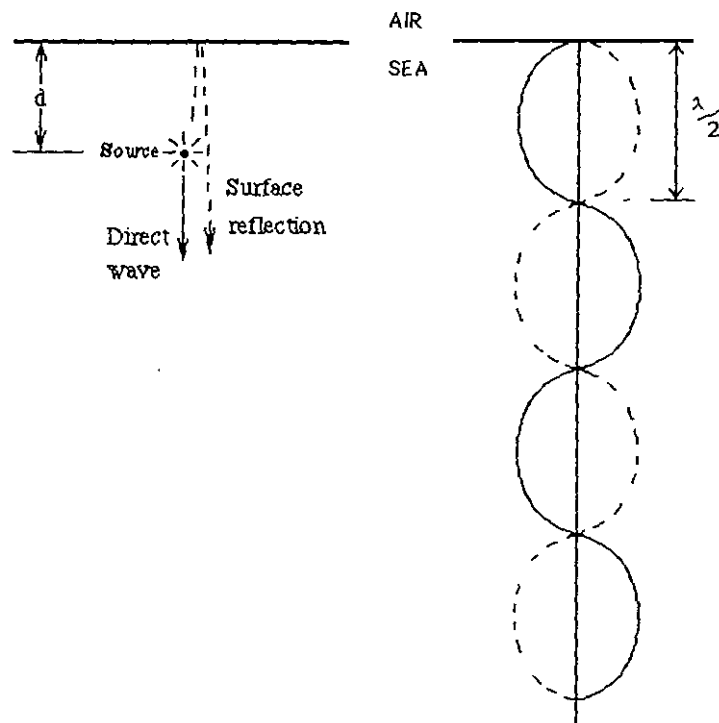


Fig. 116. Surface ghosting and sinusoidal wave cancellation.

changes the streamer depth from 5 to 15 m, while Figure 119 repeats the exercise but with the source array at 10 m. These examples show how streamer depth can affect the location of notches in the spectra and how important it is to maintain a constant source and receiver depth.

The ghost notches are not of infinite depth because of noise in the recorded signatures and their finite length. In particular, the signature truncation produces a finite DC component (at 0 Hz). This has the effect of making the ghost notch that actually occurred at $f = 0$ appear instead at about $f = 3$ Hz.

Ideally, a streamer should be towed at a depth designed to minimize the impact of the receiver ghosts on the spectrum of the seismic data. At depths of less than about 6 m, the ghost notch at $f = 0$ begins to seriously attenuate the low end of the seismic spectrum. At depths of 15 m or more, the first nonzero ghost notch affects the higher end of the spectrum. A 10-m streamer depth is a reasonable compromise that has become something of a de facto standard for streamer surveys.

For land work, the ghost becomes a real problem if good-quality recording requires the shot to be placed beneath a thick weathering layer. Ghost notch-