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A HANDBOOK FOR SEISMIC DATA ACQUISITION IN EXPLORATION

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included several technical innovations that furthered the development of seismic data acquisition equipment and the interpretation of seismic data.

Beginning in the early 1930s seismic exploration activity in the United States surged for 20 years as related technology was being developed and refined (Figure 2). For the next 20 years, seismic activity, as measured by the U.S. crew count, declined. During this period, however, the so-called digital revolution ushered in what some historians now are calling the Information Age. This had a tremendous impact on the seismic exploration industry. The ability to record digitized seismic data on magnetic tape, then process that data in a computer, not only greatly improved the productivity of seismic crews but also greatly improved the fidelity with which the processed data imaged earth structure. Modern seismic data acquisition as we know it could not have evolved without the digital computer.

During the past 20 years, the degree of seismic exploration activity has become related to the price of a barrel of oil, both in the United States (Figure 3) and worldwide. In 1990, US$2.195 billion was spent worldwide in geophysical exploration activity (Goodfellow, 1991). More than 96% of this (US$2.110 billion) was spent on petroleum exploration.

Despite the recent decline in the seismic crew count, innovation has continued. The late 1970s saw the development of the 3-D seismic survey, in which the data imaged not just a vertical cross-section of earth but an entire volume of earth. The technology improved during the 1980s, leading to more

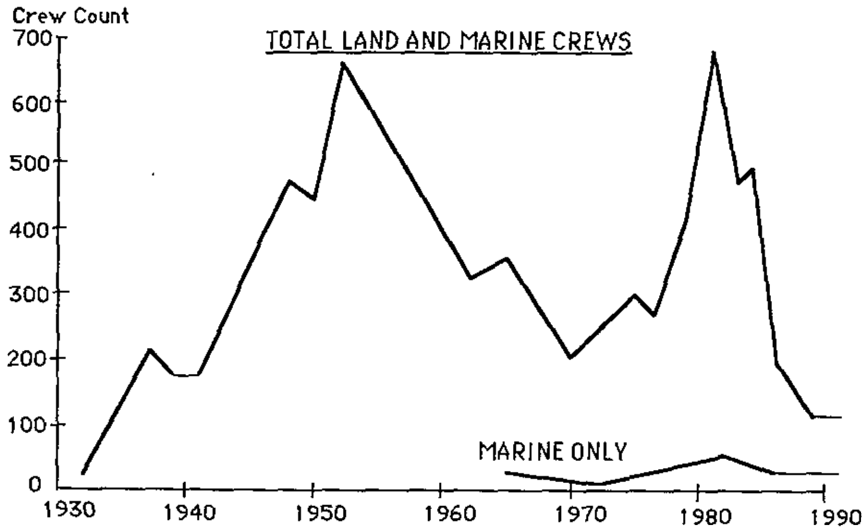

Fig. 2. U.S. seismic crew count (Goodfellow, 1991).

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

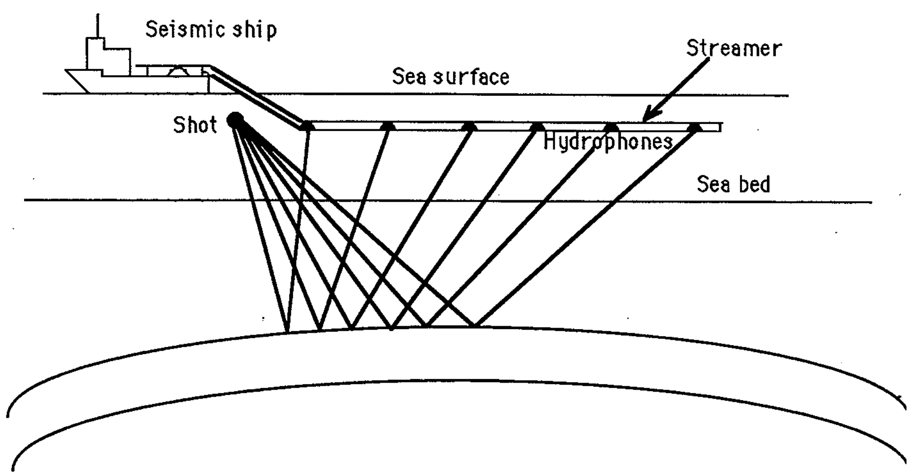

Fig. 6. Marine recording technique.

grams are generally only used in special circumstances (such as in transition zone or erratic coverage areas).

1.5 Survey Design and Planning

If we take a vertical cut through a geologic section, the direction where the geologic units are horizontal is known as the *strike direction.* A geologic section perpendicular to this direction is cut in the *dip direction* (see Figure 31).

The geology of beds is easier to understand if a 2-D profile through them is made in the dip direction rather than in the strike direction. Also, data tend to be of better quality in the dip direction. Hence, dip lines are more important than strike lines in 2-D recording. In 3-D surveying, the situation is somewhat different (see Chapter 7). In 2-D recording, lines shot in any direction other than the dip direction can be confusing to interpret. Consequently, a general idea of basin shape, orientation, or structure initially must be appreciated in order to position lines correctly. In addition, advanced 2-D migration processing is more effective with dip lines and thus a knowledge of the steepest dip direction is of extreme importance in line layout. In a new area to be mapped, seismic lines ideally should be recorded in both the dip and strike directions. The strike lines, in conjunction with the dip lines, help the interpreter form a coherent picture of an area's geology.

Line spacing is determined by the type of survey and the nature of the structure under examination. For reconnaissance work, large line spacing (50 km+) may give a regional picture, and in-fill lines with small spacing (500 m+) may be added later. If an interpreter cannot follow the geologic horizons from one line to the next during his interpretation of the data, the lines are too far apart. In 3-D surveying, the line spacing is required to be as little as 25 m in many cases to provide as detailed a geologic image as possible. Apart from geologic considerations, survey planning cannot proceed until the logis-

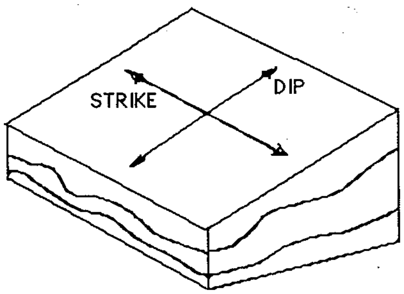

Fig. 31. Dip and strike directions.

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