Applied Drilling Engineering

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SPE Textbook Series, Volume 2

Henry L. Doherty Memorial Fund of AIME
Society of Petroleum Engineers
Richardson, TX USA

IWS EXHIBIT 1043 **EX_1043_001**

Dedication

This book is dedicated to the many students who were forced to study from the trial drafts of this work.

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Manufactured in the United States of America.

ISBN 978-1-55563-001-0
ISBN 978-1-61399-159-6 (Digital)

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Chapter 8
Directional Drilling and Deviation Control

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8.1 Definitions and Reasons for Directional Drilling

Directional drilling is the process of directing the wellbore along some trajectory to a predetermined target. Deviation control is the process of keeping the wellbore contained within some prescribed limits relative to inclination angle, horizontal excursion from the vertical, or both. This chapter discusses the principles and mechanisms associated with directional drilling and deviation control.

The preceding chapters deal with the one-dimensional process of penetrating the earth with the bit to some vertical depth. However, drilling is a three-dimensional process. The bit not only penetrates vertically but is either purposely or unintentionally deflected into the X-Y planes (see Fig. 8.1) The X plane is defined as the direction plane and the Y plane is the inclination plane. The angles associated with the departures in the X and Y planes are called "direction" and "inclination" angles, respectively.

Fig. 8.2 presents a typical example of the trajectory-control situation. Here a structure is located almost entirely under a lake. Well 1, drilled on a part of the structure that is not under the lake, could be treated simply as a deviation-control well drilled on the shore. To develop the rest of the field, however, will necessitate drilling directional wells. The only way vertical wells could be drilled would be from a floating drilling vessel or platform, with the wells being completed on the lake bed (sublake completions), or from a floating or fixed production platform; and the economics of those approaches would be far less attractive than drilling directional wells from some convenient land-based site where a standard land rig can be used. In some situations, there is no alternative to drilling a directional well. For example, the lake may be the only source for drinking water in the area, and thus there may be environmental restrictions that prohibit the use of power vessels and equipment such as offshore drilling rigs and production facilities.

The early drilling of directional wells was clearly motivated by economics. The oil fields offshore California were the spawning ground for directional drilling practices and equipment, and for a special group of people called "directional drillers." Later discoveries of oil and gas in the Gulf of Mexico and in other countries promoted the expanded application of directional drilling. Offshore field development has accounted for the majority of directional drilling activities. Fig. 8.3 shows a typical offshore platform development. In a number of cases, fields have been discovered beneath population centers, and the only way to develop the fields economically has been to use a drilling pad and to drill directionally (see Fig. 8.4). Natural obstructions such as mountains or other severe topographical features frequently prohibit building a surface location and drilling a near-vertical well (Fig. 8.5). Sidetracking out of an existing wellbore is another application of directional drilling. This sidetracking may be done to bypass an obstruction (a "fish") in the original wellbore (see Fig. 8.6) or to explore for additional producing horizons in adjacent sectors of the field (see Fig. 8.7).

Strong economic and environmental pressures have increased the use of directional drilling. In some areas it is no longer possible to develop a field by making roads to each surface location and drilling a near-vertical well. Instead, as in offshore installations, drilling pads must be built from which a number of wells can be drilled. Not only is directional drilling increasing, but trajectory programs are becoming more complicated and directional drilling is being applied in situations and areas where directional drilling has not been common. In hot-rock developments, for example, directional wells are being

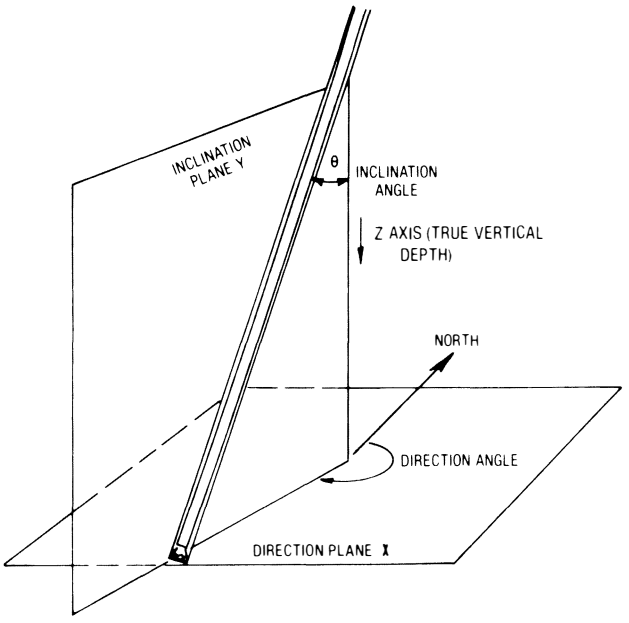

Fig. 8.1—Inclination and direction planes as a wellbore proceeds in the depth plane.

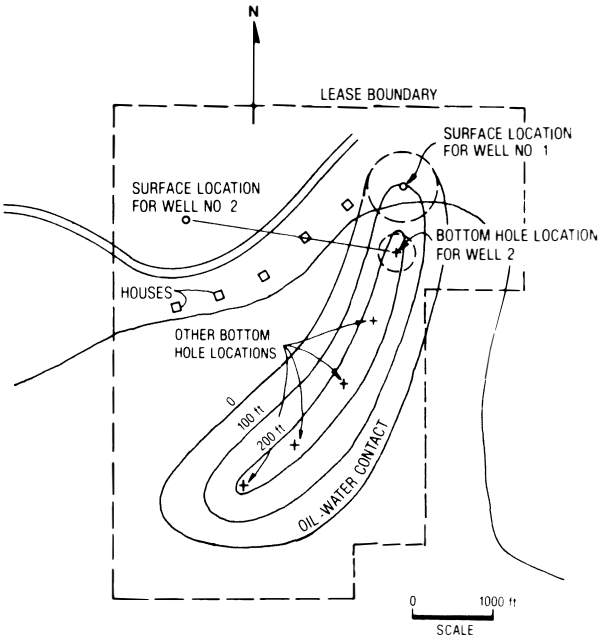

Fig. 8.2—Plan view of a typical oil and gas structure under a lake showing how directional wells could be used to develop it.

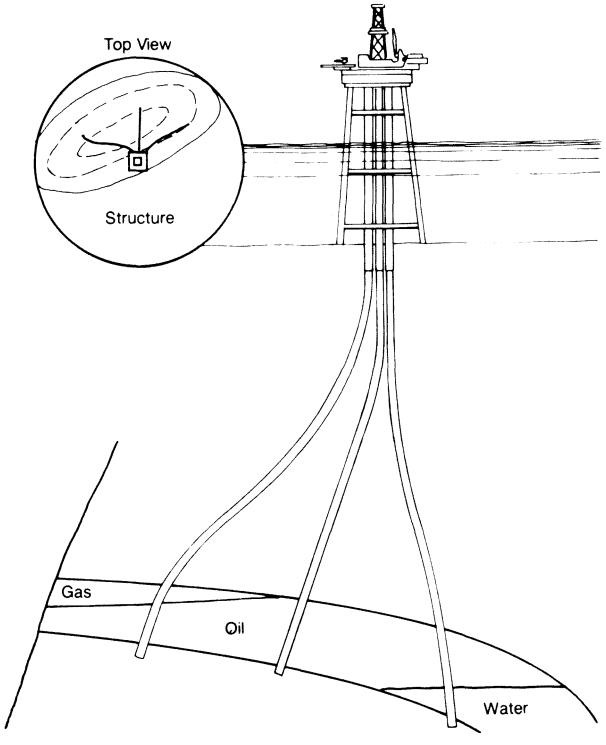

Fig. 8.3—Typical offshore development platform with directional wells.

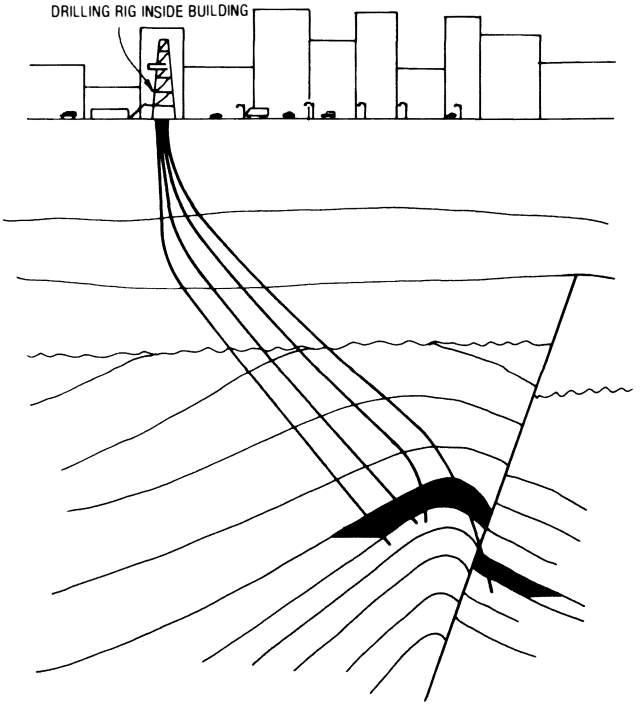

Fig. 8.4—Developing a field under a city using directionally drilled wells.

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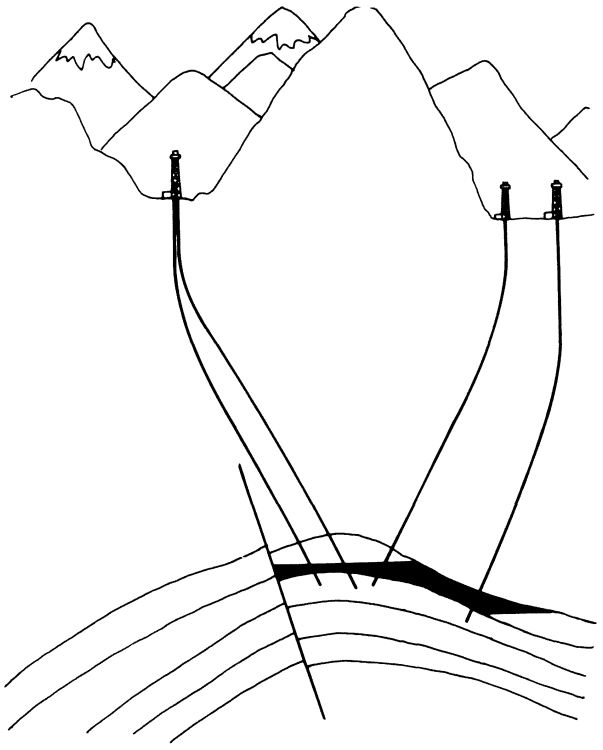

Fig. 8.5—Drilling of directional wells where the reservoir is beneath a major surface obstruction.

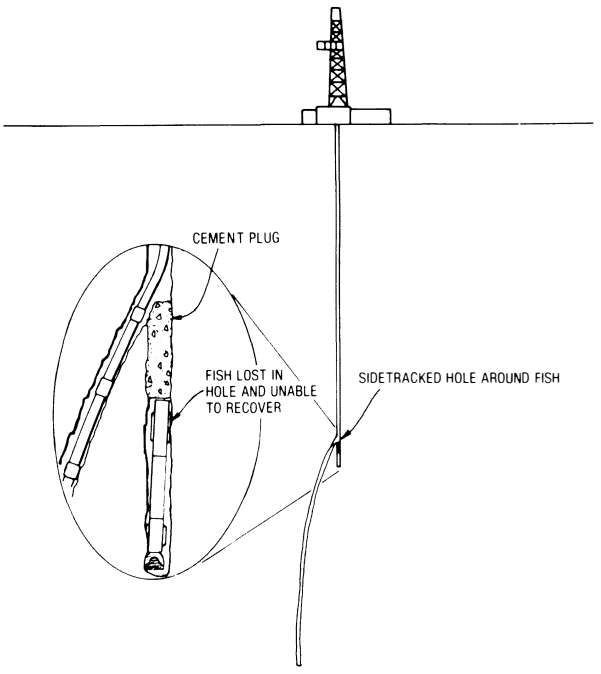

Fig. 8.6—Sidetracking around a fish.

drilled in hard granites and other igneous and metamorphic rocks. Geothermal projects have been developed with directional wells. Wells with extended horizontal reaches of 14,000 ft are being drilled, with goals of going even farther. As the costs of field development increase—in deeper waters, remote locations, hostile environments, and deeper producing zones—the use of directional drilling will also increase.

8.2 Planning the Directional Well Trajectory

The first step in planning any directional well is to design the wellbore path, or trajectory, to intersect a given target. The initial design should propose the various types of paths that can be drilled economically. The second, or refined, plan should include the effects of geology on the bottomhole assemblies (BHA's) that will be used and other factors that could influence the final wellbore trajectory. This section explains how to plan the initial trajectory for most common directional wells.

Fig. 8.8 depicts three types of trajectories that could be drilled to hit the target. Path A is a build-and-hold trajectory: the wellbore penetrates the target at an angle equal to the maximum buildup angle. Path B is a "modified-S" and C is an "S" trajectory. With the S-shape trajectory the wellbore penetrates the target vertically, and with the modified-S trajectory the wellbore penetrates the target at some inclination angle less than the maximum inclination angle in the hold section. For Path D, a "continuous-build trajectory," the inclination keeps increasing right up to or through the target. The build-and-hold path requires the lowest inclination angle to hit the target; the modified-S requires more inclination; and the S-shape requires still more. The continuous-build path requires the highest inclination of all the trajectory types to hit the target.

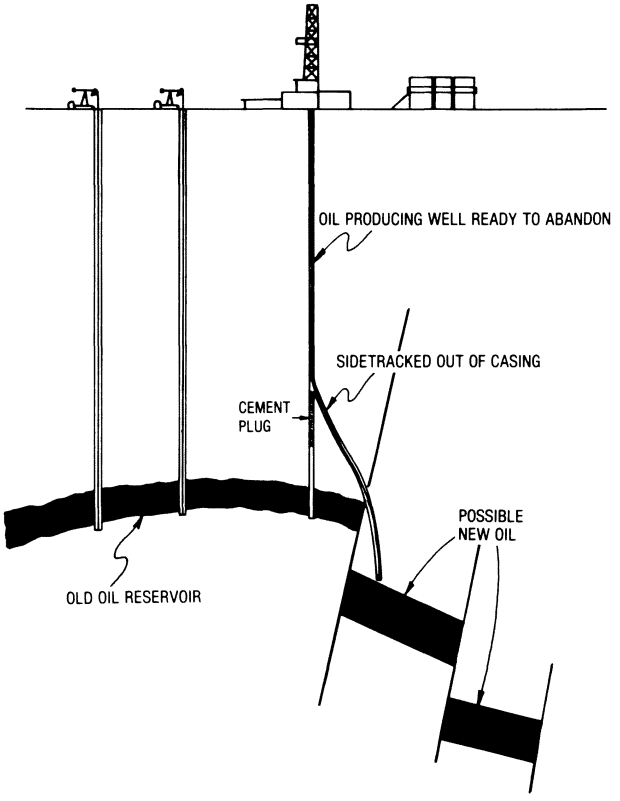

Fig. 8.7—Using an old well to explore for new oil by sidetracking out of the casing and drilling directionally.

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