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DIRECTIONAL WELLS

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ABSTRACT

This paper gives a brief overview of directional wells, the purpose of directional drilling and the drilling technique used. The majority of high-temperature wells are now directionally drilled, mainly due the reduced environmental impact and the possibility of reaching difficult targets. Worldwide there are mainly two casing programmes employed for geothermal directional wells, two types of drilling tools used to deflect the well trajectory from the vertical and two methods of logging the trajectory. The cost of directional drilling vs. conventional drilling is also mentioned.

1. INTODUCTION

The term "directional drilling" refers to the trajectory of a well when at some point it is swayed from the vertical to drill at an angle to reach a target some way laterally from the wellhead. This technology has a very long history in petroleum drilling and has been applied for geothermal wells for decades. Now the majority of high-temperature production wells are directionally drilled worldwide.

2. TARGETS OF DIRECTIONAL DRILLING

To site a drillhole results from geological mapping, and geophysical measurements are used as well as information from previously drilled holes. Production wells are drilled both vertical and directional. The main reason for directional drilling is environmental. Directional drilling makes it possible to reach under environmental difficult terrain such as mountains, valleys and gullies. It is also possible to locate the drill rig some distance away from thermal manifestations but still reach the target below the springs and fumaroles. Often wells are targeted to intersect geological features and near vertical fractures to improve the chances of success. Tentatively this is true since it is possible to intersect more than one fracture or dike in the same hole with the intention of obtaining greater output. This issue was used early on to "sell" the idea of directional drilling and justify the extra cost. However statistics from several fields around the world do surprisingly not show the directional well to be more productive on average than the vertical wells in the same field.

3. DESIGNING AND DRILLING A DIRECTIONAL WELL

The first well on a new drill site may be vertical but then 3-5 additional wells are directionally drilled from the same site, depending on the outcome of the first one. Whether directional or not the wells have virtually the same casing program (casing sizes) and are drilled with the same kind of drilling rigs with slightly greater requirements for pump power and hook load rating. Directional drilling does, however, require the use of special down-hole tools and a mud motor to deflect the well and the services of a directional drilling supervisor. Commonly two experts are required, the MWD logger and motor man, who alternate so that one is on duty while the tools are being deployed. These wells have proven trouble free to drill, not really different from vertical wells.

In directional drilling a kick-off point (KOP) is commonly at 300-400 m, just below the anchor casing, and then the inclination is built up to 30-45° and held there until total depth is reached. This means that the lateral displacement is 800-1200 m for the bottom of the well.

The casing profiles of directional wells are mainly of two types, the a) "regular" well with a diameter of 9 ⅝" for the production casing (Figure 1) and the b) "large diameter" ones with a 13 ⅜" production casing. The directional equipment to deflect the well is either by a) a steerable motor where the bit is tilted at the end of the motor or by the older method with b) a "bent sub" above the motor. By pointing the bit in the desired direction and drilling with the mud motor while the whole drill string is not rotated, will very gradually increase the inclination. The trajectory is either a) monitored with a measurement while drilling (MWD) tool in the drill string just above the motor or by b) magnetic or gyroscopic surveys run on a wireline. The preferred method is using a steerable motor and MWD, but due to cost considerations the older technology is also applied. The directional tools withstand about 120°C so they can be used for geothermal drilling even in a formation of more than 300°C as the bottom hole circulation temperature (BHCT) rarely exceeds 100°C. The directional wells are unusually not designed to be inclined more than 45° as then the drilling and logging is much the same as for vertical wells. "Horizontal" petroleum wells are now drilled (>80°) with a very long reach. It is likely that this technology will also find applications in geothermal drilling, especially where there are concerns for disturbing the natural habitat and reaching under mountains.

The drilling cost of directional drilling may be 30% higher than conventional vertical drilling due to the extra services needed. Savings in construction of multi-well pads, roads and finally pipelines to connect the wells provides the incentive to drill directional wells as it furthermore reduces the visual impact. This extra cost has also been offset in part by the use of mud motors as it has increased the rate of penetration (ROP, m/h) by a factor of two due to the higher rotational speed of the bit. The improved ROP has prompted some drilling contractors to use drilling motors beyond the building-up section of the well, for drilling the inclined well until total depth. This is possible when using a steerable motor as the bend is at the end of the motor, but not for the "bent sub" system. Then the well can be kept on track by alternating in the "rotation" and "sliding" mode, while the MWD data is available. Many times the MWD tool is taken out of the drill string when tripping for the last bit change, as to reduce the risk of losing the expensive MWD tool, should the drill string get stuck. For formations where there are magnetic reversals, gyroscopic wireline surveys are made (single shot or continuous) to confirm the readings of the MWD and the trajectory of the well. This improvement in ROP has to be balanced by the extra cost of mud motor rental and sometimes also for the MWD. In balance the overall cost of directional wells for the project as a whole is no greater than for vertical wells.

Directional drilling is also applied for drilling a so called "sidetrack" to bypass any junk or obstruction in the well. This requires the setting of a "kick-off" cement plug if it is in the open hole but inside of a casing a "window" first has to be milled with special equipment to allow the drilling assembly to exit the hole.

Lately this technology has also been applied to drill "fork" wells where a new well is drilled as a sidetrack with a different target. This is done at the time of the original drilling is cases where the first well (target) was shown not have good enough permeability. Such fork wells or sidetracks are also drilled later to rehabilitate production or reinjection wells. Directional drilling has thus become an indispensable part of modern geothermal drilling practice.

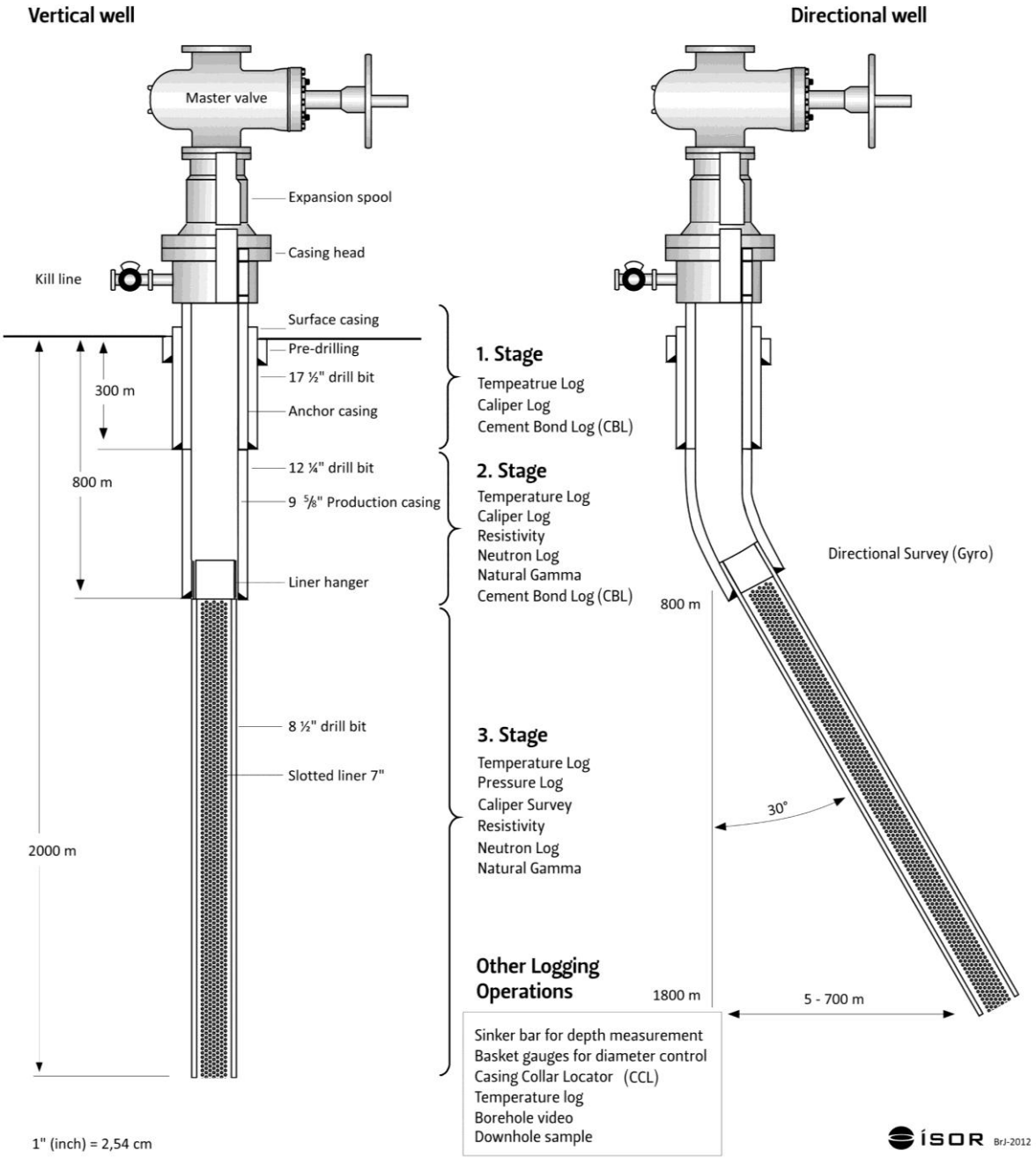

FIGURE 1: Casing program of a "regular" diameter well, vertical and directional