ELSEVIER

Journal of Applied Geophysics 36 (1996) 145–147

JOURNAL OF APPLIED GEOPHYSICS

Short Note

A supplement to 'A study of the design of inclined wellbores with regard to both mechanical stability and fracture intersection'

Shaohua Zhou [a,*], Richard Hillis [b], Mike Sandiford [b]

[a] *Geological Institute, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen, Denmark*
[b] *Department of Geology and Geophysics, The University of Adelaide, Adelaide SA 5005, Australia*

Received 3 June 1996; revised 3 June 1996; accepted 3 June 1996

Abstract

In this supplement, it is shown that, by recognizing the need to avoid hydraulically induced horizontal fractures, the predicted upper bound mud weights for mechanical stability of inclined wellbores are lower than our previous predictions (Zhou et al., 1994), and more realistic. The key conclusion remains that the mechanical stability of inclined wellbores can be improved if they are drilled with an optimum drilling direction and deviation angle.

Keywords: Inclined wellbores; Hydraulic fracture; Mechanical stability

---

1. Introduction

In our previous paper (Zhou et al., 1994), we presented a study of the mechanical stability of inclined wellbores, in which we proposed a method to predict safe drilling mud weights (which are convectionally discussed in terms of density). We determined safe drilling mud weights against drilling depth for a given combination of regional stress field, wellbore alignment and rock strength parameters. The lower bound on mud weight is the minimum weight that inhibits compressive shear failure of the wellbore wall. The upper bound on mud weight is the maximum that can be supported by the wellbore wall before inducing a hydraulic fracturing.

In this supplement, we wish to point out our previous unrealistic theoretical predictions of upper bounds on mud weight (generally > 2.5 g/cm^3, see figs. 5, 6 and 7 in Zhou et al., 1994). The stability model that we developed is correct, and the high mud weights are mechanically correct in the sense that they would not induce a vertical hydraulic fracture, given the stated stress field, wellbore alignment and rock strength. However, such high mud weights are not generally practical, given the drilling systems for, and other functions of (bit lubrication and cuttings removal) drilling mud. High mud weights were predicted because we used a high bulk rock density (2.5 g/cm^3) for the estimation of vertical stress, and only considered vertical hydraulic fracturing caused by tensile tangential stresses around the borehole wall.

2. New results

We would like to modify our previous predictions on upper bound mud weight. According to Hubbert

---

[*] Corresponding author.

PII S0926-9851(96)00032-8

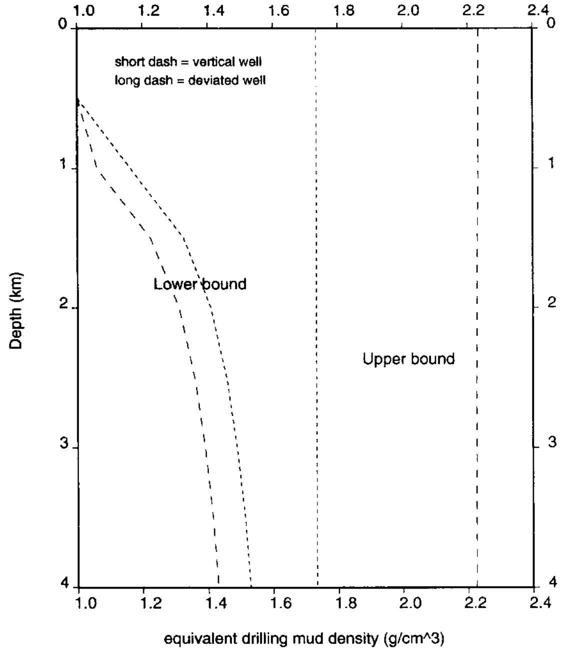

Fig. 1. Mud weight stability profile in an extensional stress regime with constant stress ratios $n_H(=\sigma_H/\sigma_v)=0.9$ and $n_h(=\sigma_h/\sigma_v)=0.5$ and the effective vertical stress gradient = 12 MPa/km. The rock strength parameters are: $C_0 = 20$ MPa (uniaxial compressive rock strength), $\mu = 0.6$ (coefficient of internal friction), $\mu = 0.2$ (Poisson's ratio) and $T = 0$ (tensile strength). The deviated well alignment, $\alpha = 90°$ (drilling direction with respect to the azimuth of σ_H) and $\beta = 55°$ (deviation angle from the vertical), is given by the optimum set of drilling direction and deviation angle as defined by the specified tectonic stress field (see Fig. 2 in Zhou et al., 1994). The pore pressure within the depth range under consideration is assumed to be hydrostatic. The lower bound mud weight does not go below water weight (1.0 g/cm^3) at depths less than 0.5 km in this example. The diagram simply illustrates there is no compressive shear failure at depths less than 0.5 km under the specified conditions of the stress field and rock strength parameters. In this example, the recommended upper bound on mud weight is 2.22 g/cm^3 (the bulk rock density).

and Willis (1957) and Jaeger and Cook (1969, p. 213), horizontal fractures can be induced if the pore pressure in the rock formation (or mud weight in the

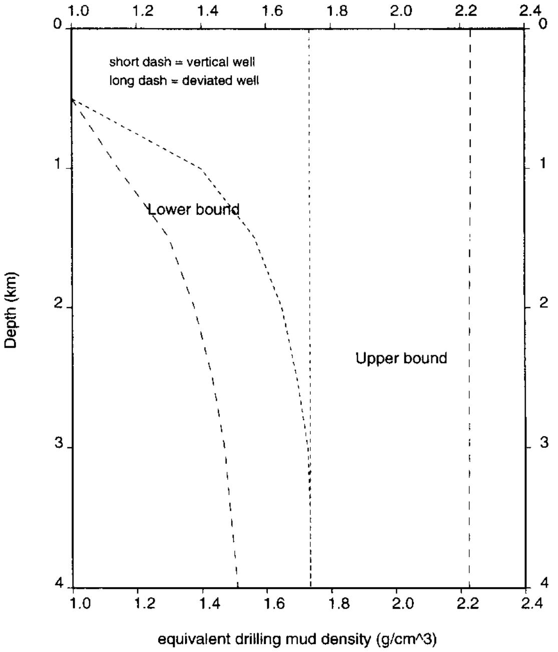

Fig. 2. Mud weight stability profile in a strike-slip stress regime with the stress ratios $n_H = 1.2$ and $n_h = 0.6$. The deviated well alignment ($\alpha = 45°$ and $\beta = 90°$) is given by the optimum set of drilling direction and deviation angle as defined by the specified tectonic stress field (see Fig. 3 in Zhou et al., 1994). Other input parameters and explanations are the same as in Figs. 1, 2 and 1.

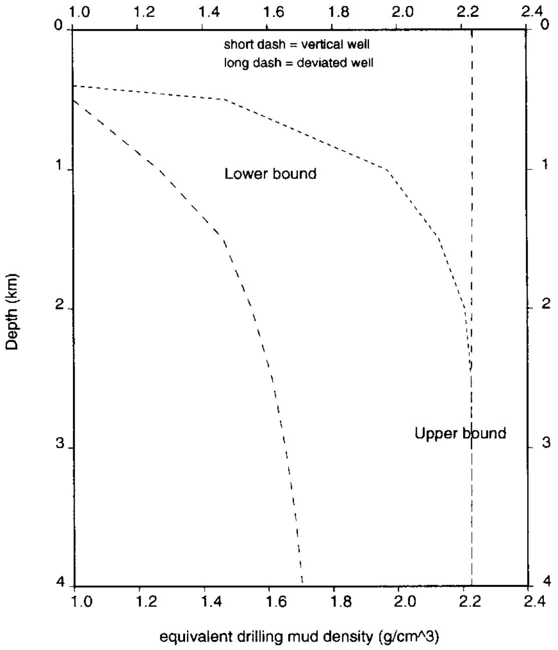

Fig. 3. Mud weight stability profile in a compressional stress regime with the stress ratios $n_H = 2.0$ and $n_h = 1.1$. The deviated well alignment ($\alpha = 0°$ and $\beta = 77°$) is given by the optimum set of drilling direction and deviation angle as defined by the specified tectonic stress field (see Fig. 4 in Zhou et al., 1994). Other input parameters and explanations are the same as in Fig. 1.

wellbore) is higher than the overburden pressure. Therefore in order to avoid hydraulically induced fractures due to mud weight exceeding either tangential stresses around the wellbore or overburden pressure, the recommended upper bound on mud weight should be the lower of the values required by the tensile tangential stress (as described in our previous paper) and overburden pressure.

In the new examples provided here (Fig. 3) a typical effective vertical stress gradient of 12 MPa/km (equivalent to a bulk rock density of 2.22 g/cm^3 with hydrostatic pore pressure) is assumed. This value is probably more appropriate for a sedimentary basin than the high value used in Zhou et al. (1994). These examples show that in regions of high stress anisotropy, the mechanical stability field (i.e. safe range of mud weights) can be much wider in a well deviated in the optimum direction than that in a vertical well. They also show that by recognizing the need to avoid hydraulically induced horizontal fractures, the predicted upper bound mud weights are lower than our previous predictions, and more realistic. It should be emphasized that this supplement does not affect other issues in Zhou et al. (1994). The key conclusion remains that the mechanical stability of inclined wellbores can be improved if they are drilled with an optimum drilling direction and deviation angle.

References

Hubbert, M.K. and Willis, D.G., 1957. Mechanics of hydraulic fracturing. J. Pet. Technol., 9: 153–168.

Jaeger, J.C. and Cook, N., 1969. Fundamentals of Rock Mechanics. Methuen and Co, London, p. 513.

Zhou, S., Hillis, R. and Sandiford, M., 1994. A study of the design of inclined wellbores with regard to both mechanical stability and fracture intersection, and its application to the Australian North West Shelf. J. Appl. Geophys., 32: 293–304.