

Comparisons of Plane Propagation from Dilating Casing and Conventional Perforations when Stimulating the Milk River Formation

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ABSTRACT: The Milk River formation, a tight-gas reservoir, is a weak mudstone within a shallow, low-energy lake environment, with thin sand lenses of upward coarsely grading sequences. Stimulation of wells in the Milk River formation are compared for a) conventional perforations in a cased hole and b) expanded dilating casings in nearby offset wells. All wells were stimulated with an energized fracturing fluid carrying 20/40-mesh sand proppant and completed at seven depth horizons. Wellhead treatment pressures for the conventionally perforated stimulations are 20 MPa at depth, rising to 27.5 MPa at the shallowest horizon. Surface tiltmeter data show fracture planes are vertical at depth and horizontal at shallower depths, with an apparent stress crossover at ~400 m depth. Wellhead treatment pressures for the split dilating casing are constant at 17.5 MPa for all depths, with all fractures vertical and no stress crossover observed. Therefore, the stress crossover is attributed as an artifact of stimulating through perforations and is not formation stress related. It is concluded that, within formations acting in the non-brittle regime, the well stimulation procedure dictates the outcome. Stimulations through perforations do not excite the least energy dissipating mechanism in non-brittle weak formations.

1. BACKGROUND

Shallow-field experiments demonstrated that vertical planes could be injected on azimuth in weakly cemented formations [1]. Continuous permeable planes filled with iron-filings proppant have been constructed using this technology for groundwater remediation at numerous sites [2]. More recently, shallow-field experiments have demonstrated that multi-azimuth permeable planes can be installed from a single well in weakly cemented formations [3]. The technology is not limited by depth but is limited to formation strength, being applicable only in weakly cemented formations.

Stimulation of weakly cemented formations is not identical to stimulation of hard rocks because the weak formation has minimal strength and zero fracture toughness. Even though the word “fracture” is a misnomer in these formations, it is used in this paper along with and synonymous to inclusion. Laboratory and near-surface experiments involving injection from a perforated casing yielded random injected geometries that are not repeatable nor develop a vertical planar injected feature. Conversely, if the casing is dilated during or just before the injection process, repeatable consistent vertical planar-injected geometries are formed

with control of the azimuth of the injected planes. In these weak formations, it is not a fracture in the conventional sense of brittle fracture, but a self-propagating inclusion caused by negative pore pressures developed at the tip of the inclusion and with the formation acting in the ductile frictional regime. To ensure the process is controlled and repeatable, the method requires (1) a dilating casing system, (2) a viscous stimulating treatment fluid, and (3) control of the pumping rate. Once the vertical planes are initiated by the dilating casing, the propagating vertical planes remain on azimuth because of the formation’s anelasticity and low horizontal-stress contrast. Pore pressure has a major influence on the inclusion propagation and its coalescence with nearby permeable inclusions.

The multi-azimuth casing prototype has been described in previous work along with its shallow field trials [3]. This earlier casing system that could install up to eight multi-azimuth wings was experimental and was not intended for commercial use. A commercial casing system was developed that, on mechanical expansion, would split along pre-aligned planes, with all wings opening the same amount and remaining locked open after expansion.