A REVIEW OF CONVENTIONAL DRILLING AND HYDRAULIC FRACTURING TECHNOLOGY AND AN ANALYSIS OF ITS CAPABILITIES TO AVOID HARMFUL CHEMICAL CROSS-CONTAMINATION OF AQUIFERS UNDER PROFESSIONAL EXECUTION

Boyan Makarenko

Edward Doheny

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Abstract

Hydrocarbons have been located and extracted from beneath the earth's surface for more than a century. The undying and exponentially growing need for readily available energy has created an enormous industry of hydrocarbon servicing companies. Recently, issues have arisen in which freshwater aquifers which supply potable water to people have been contaminated by chemicals used by these companies to extract gas or oil from underground formations. A movement was created that claims the present technology for hydrocarbon extraction is unsafe to humans and the environment. This research investigates the simple physics and engineering involved in the three unique drilling operations which can potentially contaminate an aquifer near the wellsite. Results show that mud circulation and hydraulic fracturing are inherently safe on their own, and that both the drilling company and local residents share a common interest of safety and profitability. However, the process involving cement casing, although technologically advanced enough to serve both its own purpose and the aquifer's, produces a conflict of interest between the drilling company and local residences. In cases like this, it is concluded that a third party, namely government, should enter and regulate operations.

Case I: Drilling Mud

Drilling mud is a fluid used constantly during the drilling process. It is pumped from the surface and down the well through the drillstring. When it reaches the bottom, it runs past the BHA and up the annulus of the drillstring. Once the mud reaches the surface, it runs through a mechanical separator which removes the formation cuttings severed by the drill bit. Finally, the drilling mud enters a lined pond where it is stored until once again pumped down the drillstring.

The penetration of mud into the geologic profile raises the question of cross contamination in that profile. However, the clay component in the mud is formulated to "cake" the formation at the boundary. Bentonite clay in the mud gives the mud a thixotropic characteristic. Thixotropic fluids thicken when static and thin when in motion. When the mud enters the outer regime of the formation, it slows considerably due to the impediments of solids. This allows the mud to cake almost immediately into a soft yet quite impermeable boundary. In an underbalanced well, neither formation invasion nor caking occurs; all flow is from the profile to the wellhole.

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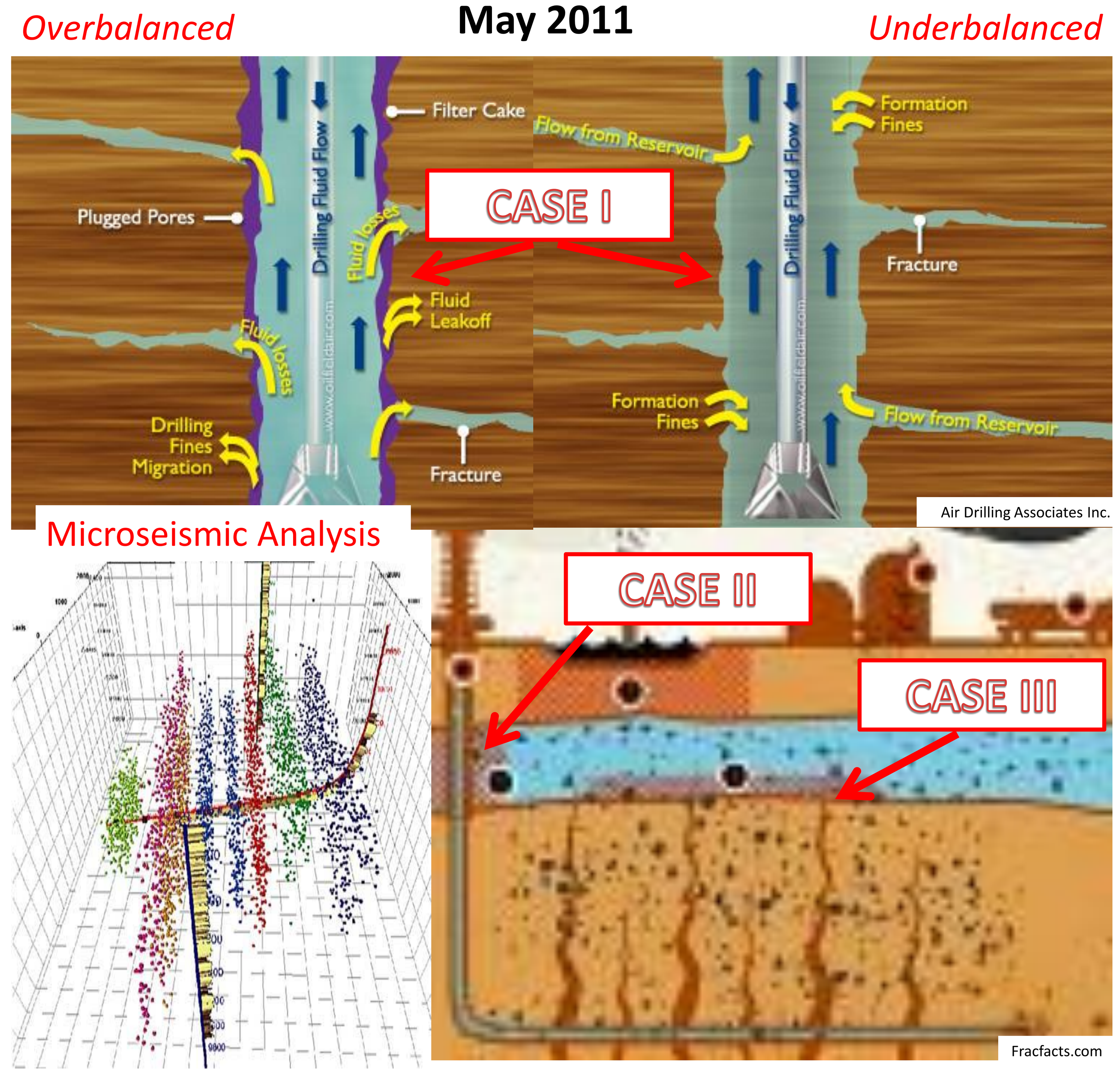


Conclusion

With respect to drilling mud and hydraulic fracturing, this paper concludes that these processes inherently do not contaminate freshwater aquifers with chemicals adverse to human health. Drilling mud has never been accused of this since technology prevents it in the first place.

This research paper claims the same argument for hydraulic fracturing. The drilling company has an interest to contain fracturing within the bounds of the hydrocarbon formation. It pays for microseismic services to monitor fractures, and it would do so even in the event where there would be no repercussions for aquifer contamination from government or lawsuits.

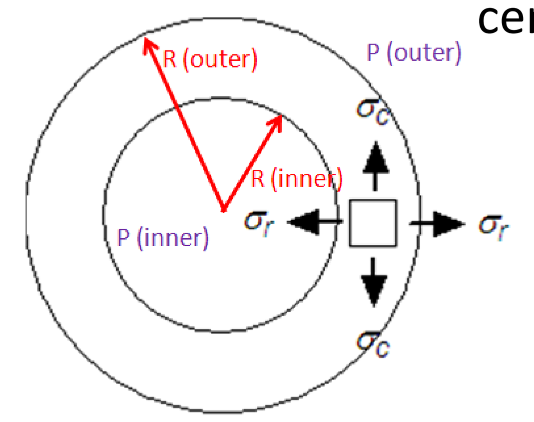
Cement casing has been the source of virtually all cross contamination claims. This case is different from the others in that company interests do not coincide with the interests of the aquifer or the residents drinking from it. The safety of the people drinking from the aquifer is indirectly proportional to well production and revenue.

In conclusion, this capstone thesis re-establishes the claim that hydrocarbon drilling and extraction is safe and that the risk to reward ratio is similar to that of any other present-day industry.

Case II: Cement Casing

A well is cased several times during the drilling process. Both formation analysis and present depth of the well play a part in deciding at what point a casing should be cemented before further drilling. A well casing is installed primarily to provide a strong and permanent barrier between the well and the formation. It must withstand the maximum pressure difference between the inside of the well and the outer formation pressures associated with the penetrated profile that will occur during the well's life.

In this phase of the drilling process, cross contamination of an aquifer can occur when the casing cracks due to an overburden of pressure differential. For our purposes, a well casing can be modeled as a thick-walled cylinder with infinite length. From the given condition, a drilling engineer will have prior logs quantifying the outer pressure produced by the formation. He will also be aware of the maximum pressure the inner wall will succumb to (most likely fracking). The outer radius is given to be the distance from the well center to the well wall. Therefore, the only variable in this case will be the inner radius of the casing. It is up to the engineer to decide what this dimension should equate to (with a sufficient factor of safety) in order to prevent the cement casing from failing.



$$\sigma_{c,max} = \frac{p_i r_i^2 - p_o r_o^2}{r_o^2 - r_i^2} - \frac{r_o^2 (p_o - p_i)}{(r_o^2 - r_i^2)}$$

$$p = pressure;\ r = radius;\ o \rightarrow outer;\ i \rightarrow inner$$

Case III: Hydraulic Fracturing

This section deals with the potential of frack fluid contaminating an aquifer through the fracturing procedure (contamination through the fractures themselves). In a horizontal well, this would happen through the migration of a vertical crack upwards until it makes contact with an aquifer. A fracture will propagate in the path of least resistance. Presently, there exists an advanced technology in monitoring hydraulic fracturing migration called microseismic. It triangulates a seismic event and locates it in the same way the USGS monitors earthquakes. The microseismic technique has been used for many years and has developed into an accurate tool for tracking and modeling hydraulically induced fractures in a geologic profile. Although some uncertainty exists with event location, it is orders of magnitude less than that required to avoid penetrating a foreign formation, let alone a distant aquifer. This statement is backed up with the fact that all groundwater well contaminations due to hydrocarbon drilling have been accounted for as either due to natural gas migration or faulty cement casing. No well contaminations have been specifically linked to upward migration of hydraulic fracturing.