[EA]Sanding Problems in Injection and Production Wells of Waterflood Projects*

Amr Sayed[1] and Mahmood Amani[1]

Search and Discovery Article #42353 (2019)**
Posted February 11, 2019

*Adapted from extended abstract based on poster presentation given at 2018 International Conference and Exhibition, Cape Town, South Africa, November 4-7, 2018
 DOI:10.1306/42353Sayed2019

[1]Texas A&M University at Qatar, Doha, Qatar (amani@tamu.edu)

Abstract

Sanding problems associated with oil production in waterflooding operations have been a common phenomenon at water breakthrough especially when producing from chalk and weak consolidated sand formations (Han and Dusseault, 2002). This topic has been researched extensively because of the severity of the potential damage that could be caused by sand erosion (Fjaer, 2008, Chapter 10; Skjaerstein, Tronvoll, Santarelli, and Joranson, 1997). On the other hand, until very recently sanding in water injectors did not receive the same attention from operators and researchers, as it was not seen possible given the pressure gradient imposed during injection (Morita, Davis, and Whitebay, 1998; Frederic J. Santarelli, Sanfilippo, Embry, White, and Turnbull, 2011). Sanding, however, is now consider as a major contributor to injectivity decline or the sudden and complete injectivity lost observed in some water injectors (F.J. Santarelli, Skomedal, Markestad, Berge, and Nasvig, 2000). The aim of this paper is to review the main mechanisms contributing to sanding in production and injection wells of waterflooding operations and to present available solutions and practices to prevent or reduce the effect of the problem.

Oil Producing Wells

For conventional oil producing wells, sand production can be a serious problem as it could increase erosion rates as well as the risk of catastrophic failures in subsurface equipment and surface facilities. It could also cause filling of the borehole that might lead to the abandonment of the well (Eisa and Abdel Waly, 2007; Fjaer, 2008, Chapter 10). On the other hand, some studies (Papamichos, 1999; Tronvoll and Fjaer, 1994) showed that sand production could have a positive impact on wells' productivity and help mitigate damaged low permeability material around the wellbore. Intentionally producing sand in heavy oil producing wells is considered the only economical way to produce, in a process called CHOPS (Cold Heavy Oil Production with Sand), excluding the use of thermal recovery methods.

Causes of Sand Production in Producing Wells

Operators of many water injection projects observed that sand production in producing wells coincide with water breakthrough. There are two main factors leading to the change of sand stability at elevated water saturation: chemical reactions between the rock and the formation waters, and change in capillary strength at different water saturation values. The response of capillary strength to elevated water saturation is much faster than chemical reactions; therefore, capillary strength might be the dominant influencer in sand production at the beginning of water breakthrough. While chemical reactions may have a bigger role later at higher water saturations.

Chemical Reactions

Many chemical reactions can take place between Quartz, the most common mineral and an important cementation in sandstone reservoirs, and the "new" formation water. However, almost all these reactions either require very high temperatures (200ºC to 500ºC) or need a long time to yield the observed results. The only feasible reaction under normal water injection operations is hydrolytic weakening based on Frank-Griggs hypothesis, which eliminates the need for breaking Si-O bonds for dislocation motion to occur and instead attribute it to hydrogen bond exchange (Griggs, 1967; Han and Dusseault, 2002).

Sandstone rocks with calcareous cementation could be weakened with water by dissolution reactions at water breakthrough. For sandstones with smectite clay, swelling could significantly affect rocks' strength by decreasing its permeability when in contact with water with different chemistry. Because clay swelling decreases flow path (permeability), this causes an increase in the local pressure gradient and the seepage forces which destabilize the sand (Fjaer, 2008, Chapter 10; Han and Dusseault, 2002).

Capillary Strength

The other factor affecting sand strength is the consequences of the decrease in rocks' capillary force at water breakthrough. As shown in Figure 1 and Figure 2 (generated using a model), an elevation in water saturation decreases the capillary cohesive force, and therefore, rocks' strength resulting from this force, such as the tensile strength and the uniaxial compressive strength (UCS). Capillary strength can decrease dramatically from several kPa to zero within only 5% increase in water saturation. For oil wells that start to produce water (at water breakthrough) Han and Dusseault (2002) suggest to automatically treat the capillary strength as zero.

Figure 1 shows that capillary strength has a linear relationship with the surface tension between the two liquids in the rock. To illustrate, a typical value of surface tension for a system of water and heavy oil lies between 0.015 to 0.02 N/m, and around 0.038 N/m between water and silicon oil. Figure 2 shows the dramatic drop in rocks' tensile strength with an increase in particle size, with is usually less than 0.5 mm in sandstone formations. (Han and Dusseault, 2002)

Solutions and Recommendations

Sand production is usually measured/observed at the surface; assuming that production is high enough to transport sand grains from the formation. The main preventative solutions to deal with sanding problems downhole include the use of gravel packing or screens in wells' completions. Chemical consolidation might be used to strengthen the formation by injecting a resin. Further, frac-packing is sometimes used in low permeability formations, where fractures are created into the formation and filled with proppants. These sand control methods usually increase well costs and might reduce its productivity or cause clogging problems (Fjaer, 2008, Chapter 10).

Water Injection Wells

Unlike sand production in producing wells, there is no available method to monitor sand production in water injection wells. The first sign of the problem might only be realized with a significant injectivity decline. Sanding in injection wells could even lead to the complete loss of the well; as result of sand covering the injection interval.

There is very little literature addressing this issue, compared to sanding in producing wells. However, some research has been conducted in effort to predict sand problems in water injectors by modeling the factors affecting near wellbore rock disaggregation during injection operations (Azadbakht et al., 2012; Bautista and Taleghani, 2016; Kjorholt, Joranson, Markestad, Raaen, and Viken, 1998; Vaziri, Nouri, Hovem, and Wang, 2008).

It should be noted that the pressure difference required to trigger sanding after shutdown is much smaller in injection wells; mainly because sand around these injectors is under very low effective stress. Therefore, it is more likely to be produced when compared to production operations where the drawdown associated with shutdown can compact the disaggregated sand around the wellbore.

Causes of Sand Production in Injection Wells

Sanding occurs in water injectors drilled in weak/ poorly consolidated reservoirs due to many factors at which the most important are: injection pressure, water hammer pulses, crossflow in multilayers formations/ permeability heterogeneous intervals, and repetitive shutdowns of the well (F.J. Santarelli et al., 2000; Vaziri et al., 2008).

Backflow and Crossflow

Although no sand production is expected during water injection, shutdown of injectors can trigger backflow or crossflow between layers and intervals with a considerable difference in permeability values (flow from low to higher permeability). This can cause near wellbore sand disaggregation and eventually sand production. The produced sand will be reinjected into the perforations when operations is continued; consequently, leading to steady and progressive injectivity decline (Vaziri et al., 2008). Santarelli et al. suggest that in some cases allowing enough time for sand particles to settle down in the rat-hole between shutdowns and reopening the well can reduce the significance of this phenomenon on the injectivity, the mechanism to support this argument is illustrated in Figure 3.

Water Hammer

Water hammer results from rapid well shutdowns that occur due to emergency power shutdowns in the pumps. The sudden stop of liquids in the pipes creates a pressure wave that travels across the system then reflects back when it reaches the bottom of the well. This pulse travels at a velocity depending on the geometry of the pipes and the stiffness of its material. The water hammer pulse can cause sand liquefaction at the weakened interval (causes sand to behave like slurry) leading to a sudden and complete well loss. An example of the dramatic effect this phenomenon can carry was recorded in waterflooding operation at the Norwegian Sea where a well went from 8,000 to 0 m^3/d in just half an hour (F.J. Santarelli et al., 2000).

Injection wells' sudden complete loss of injectivity, observed in some field operations, is a clear consequence of sand liquefaction triggered water hammer waves. Sand liquefaction causes sand to behave like a slurry and fill the well. This can be encountered in injection wells that underwent an increase in porosity around the perforation intervals, which, in return, was caused by earlier sand production.

Solutions and Recommendations

Sanding intensity in injection wells could be reduced by optimizing injection pressure, reducing the frequency of shutdowns, designing well/pipes configuration to reduce water hammer pulses (this include pump location, and type of valves, etc.) and avoid placement of subsurface tools that leads to stiffer fluid columns. It is also recommended to drill longer ratholes in injection wells, to allow more sand to settle before it covers the injection interval. Sand control completions, like Frac packing, can provide a good solution even at weak formation; however, employing this might not be feasible for wells designed for high injection rates (F.J. Santarelli et al., 2000; Vaziri et al., 2008).

Conclusion

Sand production can cause severe problems in the injection and production wells of waterflooding projects. In oil producing wells, sand production at water breakthrough is caused by in situ chemical reactions with the water, and the change in capillary strength at elevated water saturation. While in water injectors, the problem is associated with cross/back flow and water hammer triggered by shutdowns. Sand control completion might not always be an ideal solution, as it usually reduces the productivity of oil wells and dictates a maximum injection rates for water injectors. Different other preventive and mitigating practices could be applied depending on the well and the severity of the problem.

References Cited

Azadbakht, S., M. Jafarpour, H. Rahmati, A. Nouri, H. Vaziri, and D. Chan, 2012, A Numerical Model for Predicting the Rate of Sand Production in Injector Wells: in SPE Deepwater Drilling and Completions Conference, Society of Petroleum Engineers, http://doi.org/10.2118/156394-MS

Bautista, J.F., and A.D. Taleghani, 2016, Prediction of Formation Damage at Water Injectors Wells due to Channelization in Unconsolidated Formations: in SPE International Conference and Exhibition on Formation Damage Control, Society of Petroleum Engineers, http://doi.org/10.2118/179032-MS

Eisa, I.E., and A.W.A. Abdel Waly, 2007, Effect of Water Injection on Sand Production Associated With Oil Production in Sandstone Reservoirs: in SPE/IADC Middle East Drilling and Technology Conference, Society of Petroleum Engineers, http://doi.org/10.2118/108297-MS

Fjaer, E., 2008, Petroleum related rock mechanics: Elsevier.

Griggs, D., 1967, Hydrolytic Weakening of Quartz and Other Silicates: Geophysical Journal of the Royal Astronomical Society, v. 14/1–4, p. 19–31, http://doi.org/10.1111/j.1365-246X.1967.tb06218.x

Han, G., and M.B. Dusseault, 2002, Quantitative Analysis of Mechanisms for Water-Related Sand Production: in International Symposium and Exhibition on Formation Damage Control, Society of Petroleum Engineers, http://doi.org/10.2118/73737-MS

Kjorholt, H., H. Joranson, P. Markestad, A.M. Raaen, and R. Viken, 1998, Advanced Sand Prediction in a User Friendly Wrapping: in SPE/ISRM Rock Mechanics in Petroleum Engineering, Society of Petroleum Engineers, http://doi.org/10.2118/47333-MS

Morita, N., E. Davis, and L. Whitebay, 1998, Guidelines for Solving Sand Problems in Water Injection Wells, In SPE Formation Damage Control Conference, Society of Petroleum Engineers, http://doi.org/10.2118/39436-MS

Papamichos, E., 1999, Sand production and well productivity in conventional reservoirs: Retrieved from https://www.onepetro.org.ezproxy.library.tamu.edu/conference-paper/ARMA-99-0209?sort=&start=0&q=sand+production&from_year=&peer_reviewed=&published_between=&fromSearchResults=true&to_year=&rows=50#

Santarelli, F.J., F. Sanfilippo, J.-M. Embry, M. White, and J.B. Turnbull, 2011, The Sanding Mechanisms of Water Injectors and their Quantification in Terms of Sand Production: Example of the Buuzard Field (UKCS): in SPE Annual Technical Conference and Exhibition, Society of Petroleum Engineers, http://doi.org/10.2118/146551-MS

Santarelli, F.J., E. Skomedal, P. Markestad, H.I. Berge, and H. Nasvig, 2000, Sand Production on Water Injectors: How Bad Can It Get? SPE Drilling & Completion, v. 15/2, p. 132-139, http://doi.org/10.2118/64297-PA

Skjaerstein, A., J. Tronvoll, F.J. Santarelli, and H. Joranson, 1997, Effect of Water Breakthrough on Sand Production: Experimental and Field Evidence: in SPE Annual Technical Conference and Exhibition, Society of Petroleum Engineers, http://doi.org/10.2118/38806-MS

Tronvoll, J., and E. Fjaer, 1994, Experimental study of sand production from perforation cavities: International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, v. 31/5, p. 393-410, http://doi.org/10.1016/0148-9062(94)90144-9

Vaziri, H.H., A. Nouri, K.A. Hovem, and X. Wang, 2008, Computation of Sand Production in Water Injectors: SPE Production & Operations, v. 23/4, p. 518-524, http://doi.org/10.2118/107695-PA

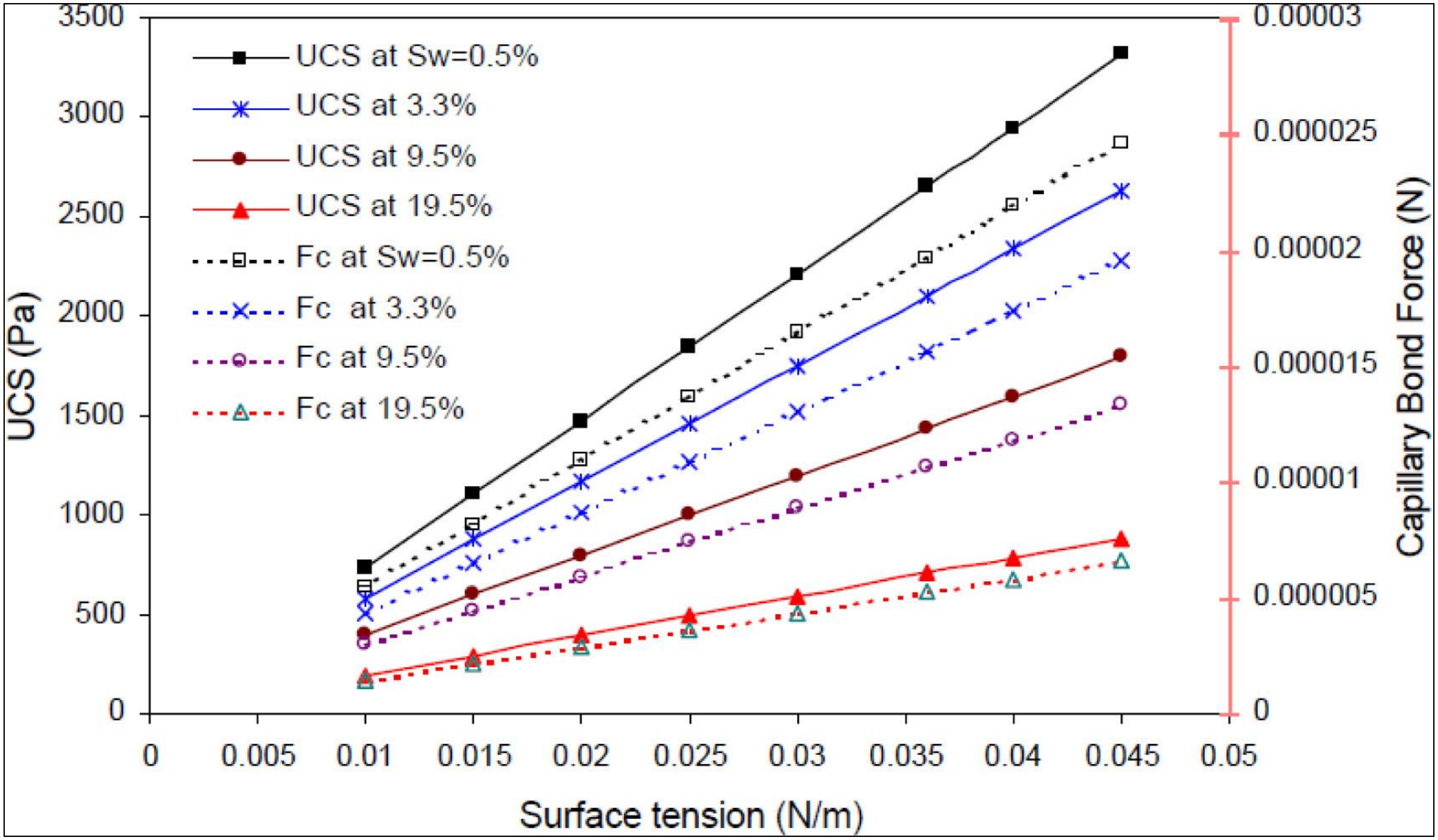

Figure 1. Capillary force and USC verses surface tension at different water saturation for an average particle size of 0.1 mm (Han and Dusseault, 2002, fig. 10).

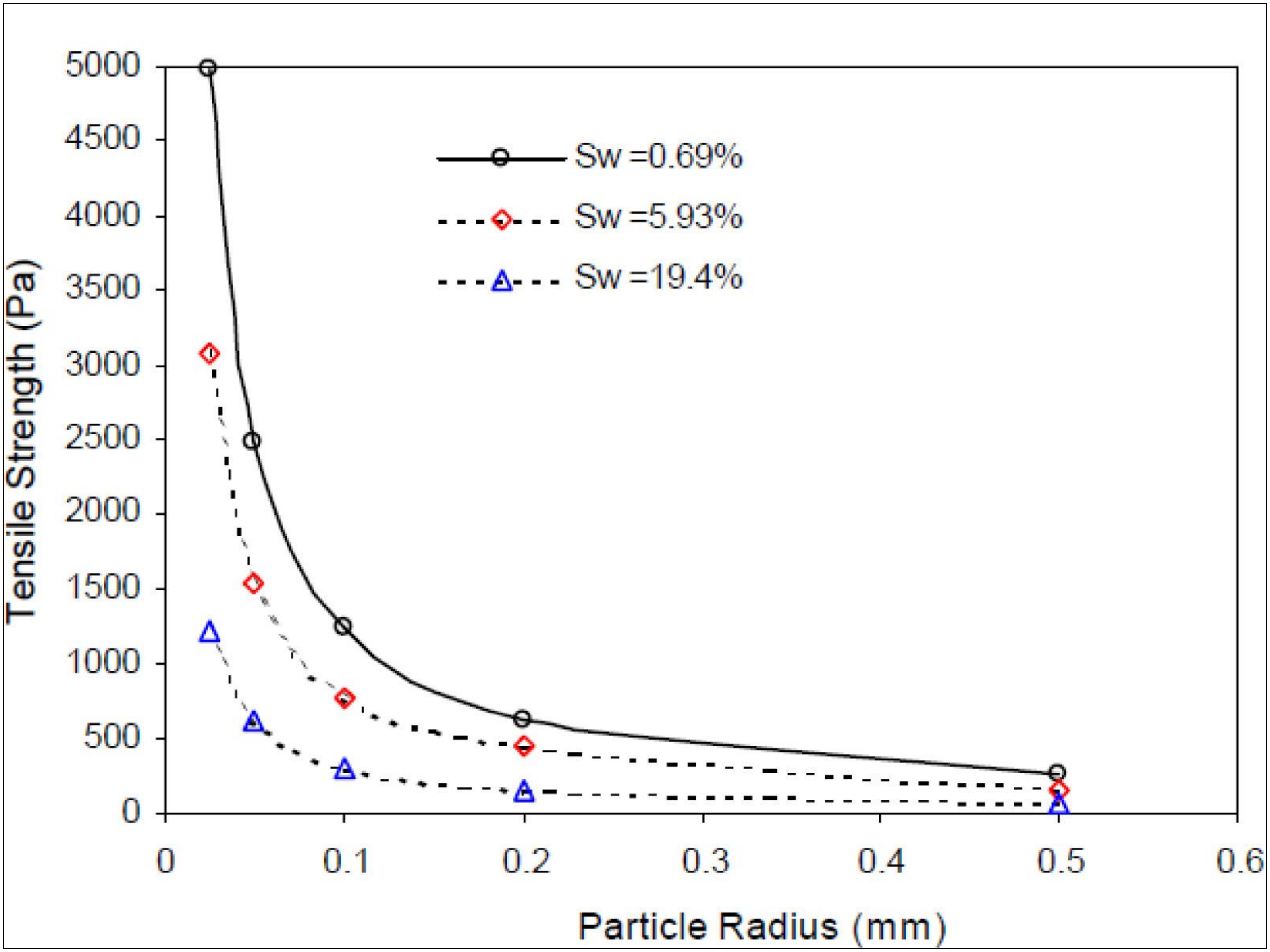

Figure 2. Rock Tensile strength versus particle size at different water saturations for surface tension of 0.036 N/m and pressure gradient of 20 kPa/m (Han and Dusseault, 2002, fig. 11).

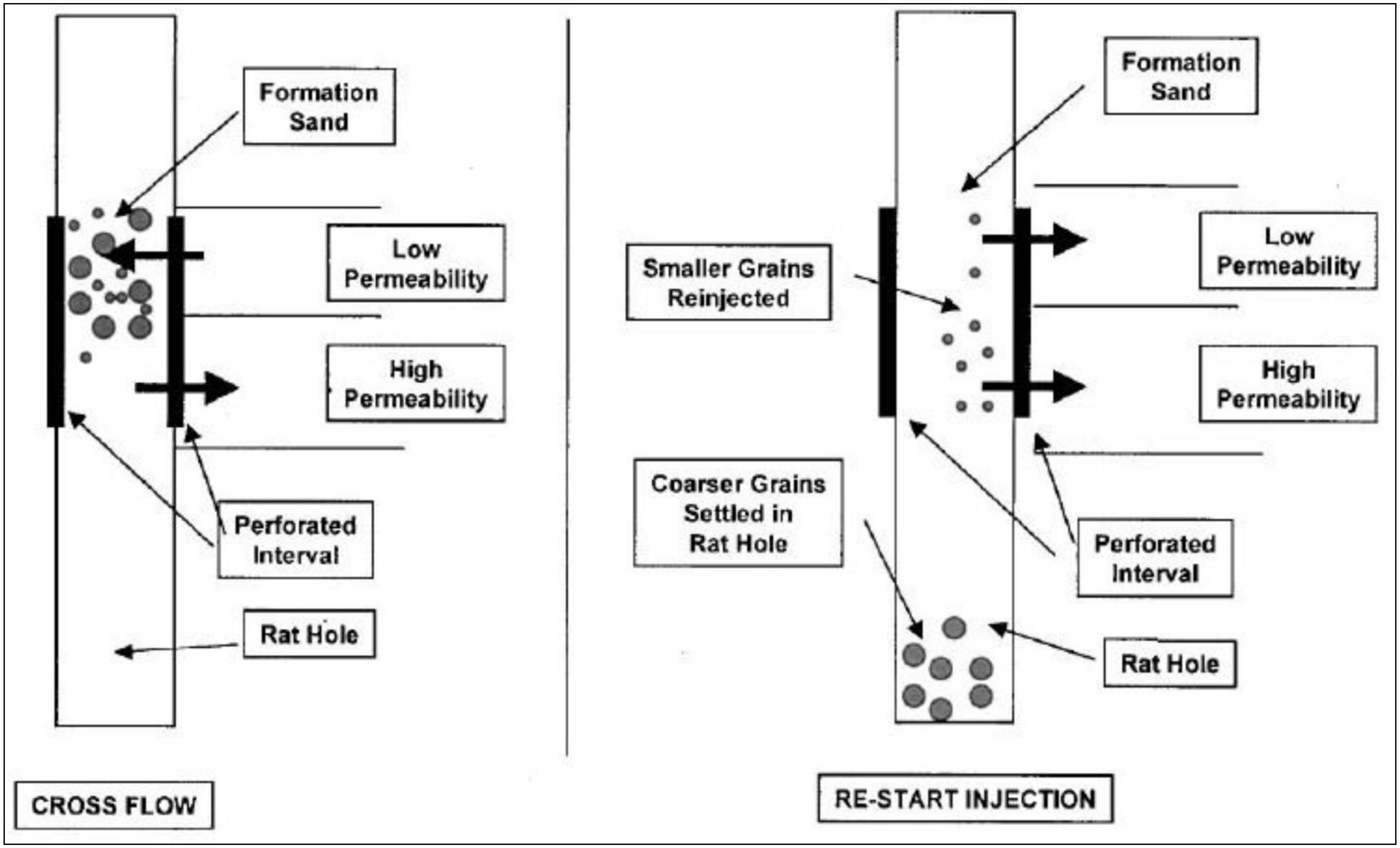

Figure 3. A schematic of crossflow triggered injectivity decline (F.J. Santarelli et al., 2000, fig. 5)