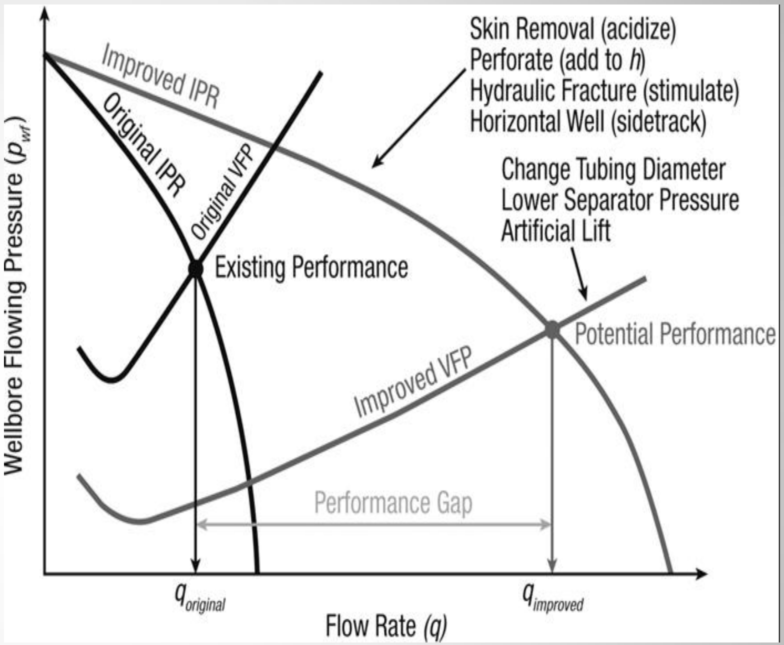
Lecture 15-16

Mechanical Methods to increase the Productivity of Wells

WELL PRODUCTIVITY

- An ideal well productivity is the final goal of Production Optimization. In particular, well productivity is determined by a well inflow performance and in this context, a common approach is "Nodal Analysis". It is a system analysis approach applied to analyze the performance of systems composed of interacting components.

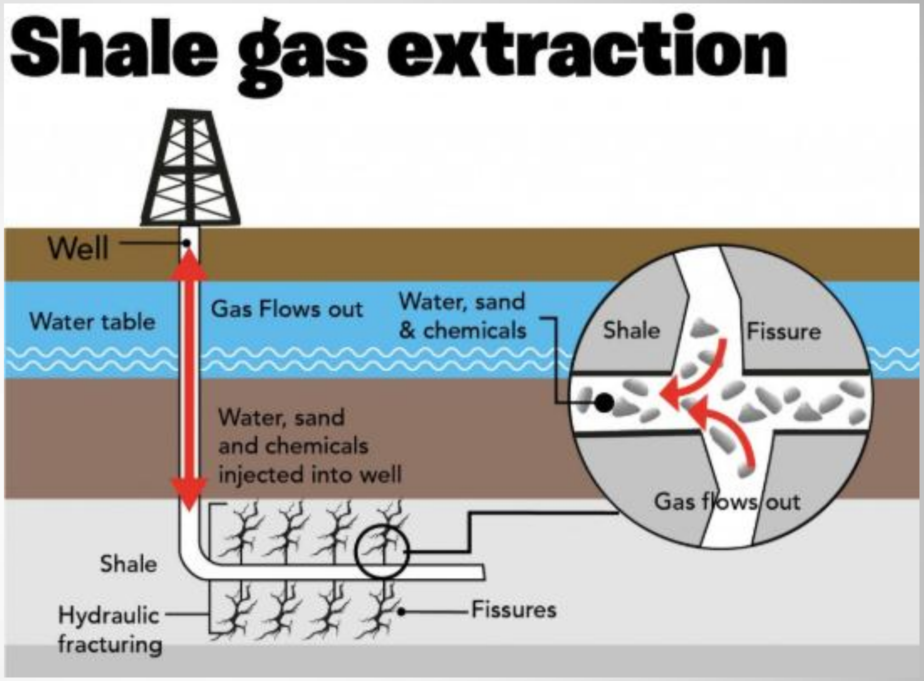


$$J = \frac{q}{p - p_{wf}} = \frac{kh}{\alpha_r B \mu} J_D$$

$$J_D = \frac{1}{\ln\left(\frac{r_e}{r_w}\right) + s}.$$

HYDRAULIC FRACTURING

- In general, hydraulic fracture treatments are used to increase the productivity index of well of a producing well or the injectivity index of an injection well. The productivity index defines the rate at which oil or gas can be produced at a given pressure differential between the reservoir and the wellbore, while the injectivity index refers to the rate at which fluid can be injected into a well at a given pressure differential.



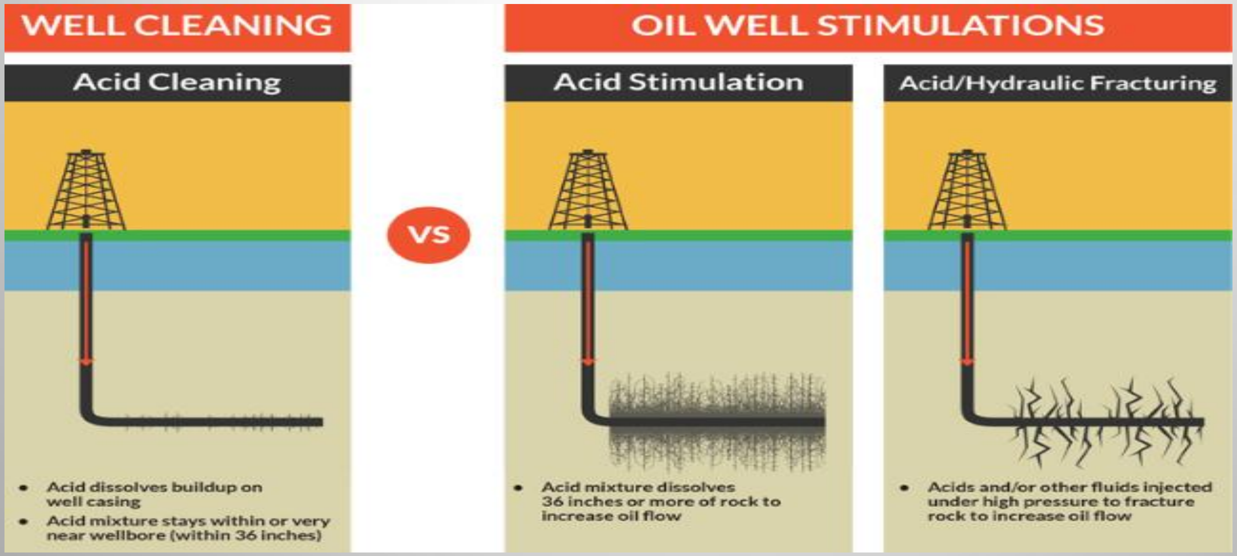
$$\frac{Q}{N} = \frac{D_p^2 \times C_d \times \sqrt{\frac{P_f}{\rho}}}{0.487}$$

There are many applications for hydraulic fracturing. Hydraulic fracturing can:

- Increase the flow rate of oil and/or gas from low-permeability reservoirs
- Increase the flow rate of oil and/or gas from wells that have been damaged
- Connect the natural fractures and/or cleats in a formation to the wellbore
- Decrease the pressure drop around the well to minimize sand production
- Enhance gravel-packing sand placement

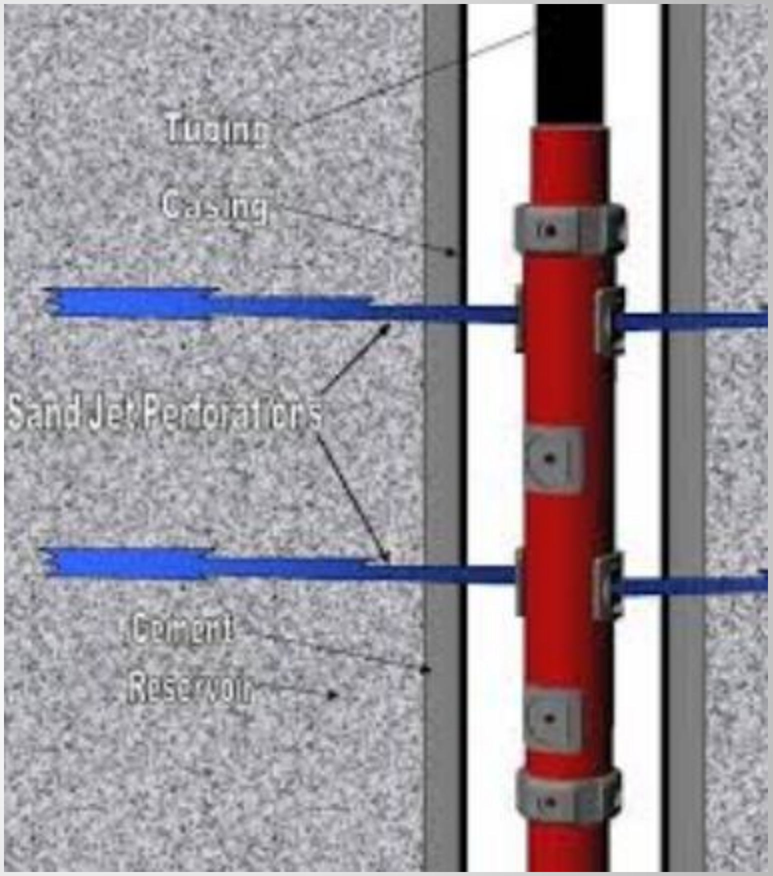
WELL STIMULATION

- Well stimulation is a term describing a variety of operations performed on a well to improve or increase its productivity. Stimulation operations can be focused on the wellbore or on the reservoir. They can be conducted on old wells and new wells and they can be also designed for remedial purposes. There are two main types of stimulation operations: matrix stimulation and hydraulic fracturing. Matrix stimulation is performed below the reservoir fracture pressure in an effort to restore the natural permeability of the reservoir rock.



JET PERFORATION AND ANNULAR FRACTURING

- This is a fracturing technology with layers sep-arated finely by means of sand plugs to separate all the fracturing layers. In this technology, coiled tubing sand jet perforation will be conducted in casing completion and main fracturing operations will be done in the annular space.



$$d = \sqrt{\frac{4Q}{pu}} = \sqrt{\frac{4Q}{pC\sqrt{2p/\rho}}}$$

PORO-ELASTIC TENSILE FAILURE

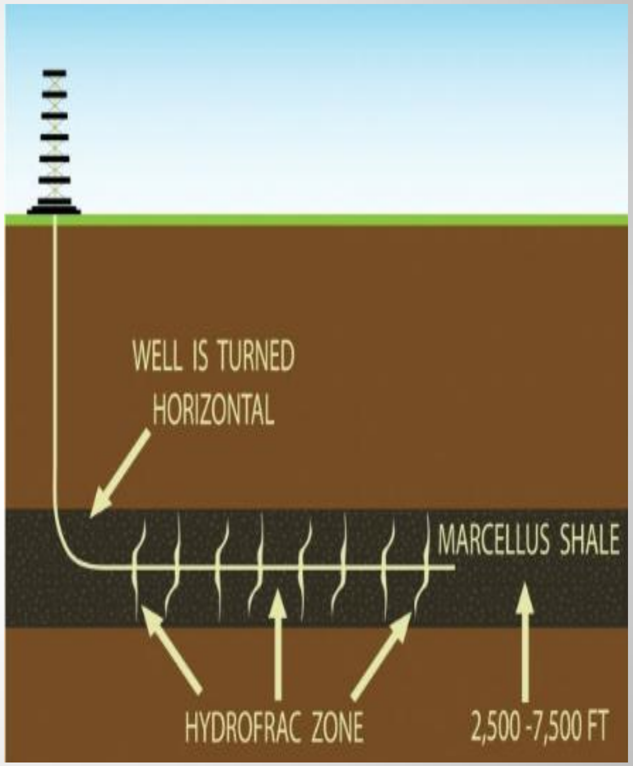
- a rapid fluid pressure decrease at the rock surface will induce effective tensile stresses in the formation equal to the decrease. If this induced tension is higher than the sum of the smallest effective stress in the formation and the tensile strength, the rock will fail in tension. This induced tension occurs as the compressibility of the rock grains and pore fluid is not equal, and any deviation from equilibrium between the rock grains and pore fluid has to be restored by fluid flowing through the pore space. This flow takes time due to the finite permeability of the rock, and gives rise to this transient poroelastic effect. However, for high permeability sandstones (1 Darcy) the time scale is around 1μs, which may be unrealistically fast. However, the time scales inversely with the permeability and for chalk (1 md) or shale (1 mDarcy) this effect may be important

SURFACE EROSION

- is the process where the rock fragments are removed from the surface of the rock due to the shear and compression forces exerted on the rock surface due to jetting force

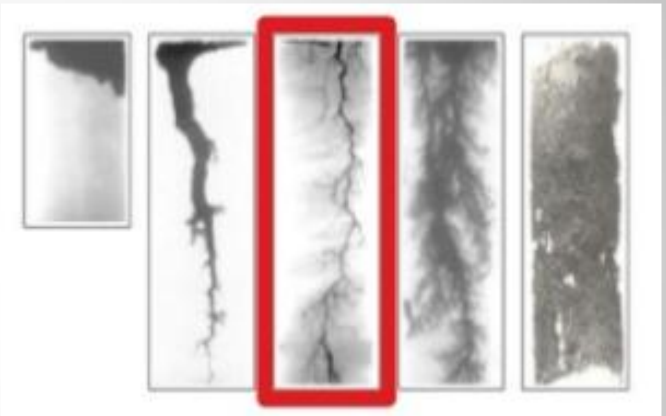
FRACTURING HORIZONTAL WELLS

- In recent years, hydraulic fracturing technology has witnessed major advances, as its use has been the main driver for production from tight oil and gas reservoirs in the US and Canada. In these applications, numerous hydraulic fractures are created along the length of an open or cased horizontal well to gain access to large volumes of the low-permeability reservoir. The number of fractures in cased horizontal wells can be as many as 60 to 70. In both applications, the volume of fluid and weight of proppant is at least an order of magnitude larger than what is used in vertical wells. Hydraulic fracturing has played a very important role in enabling the oil and gas industry to meet the energy needs of the growing world. As we are forced to rely on more marginal reservoirs for meeting our energy requirements, the need for better fracturing technology becomes even more pressing. This is best demonstrated by the recent rapid development and deployment of novel fracturing tools and techniques that are specifically suited for horizontal wells.



MATRIX ACIDIZING

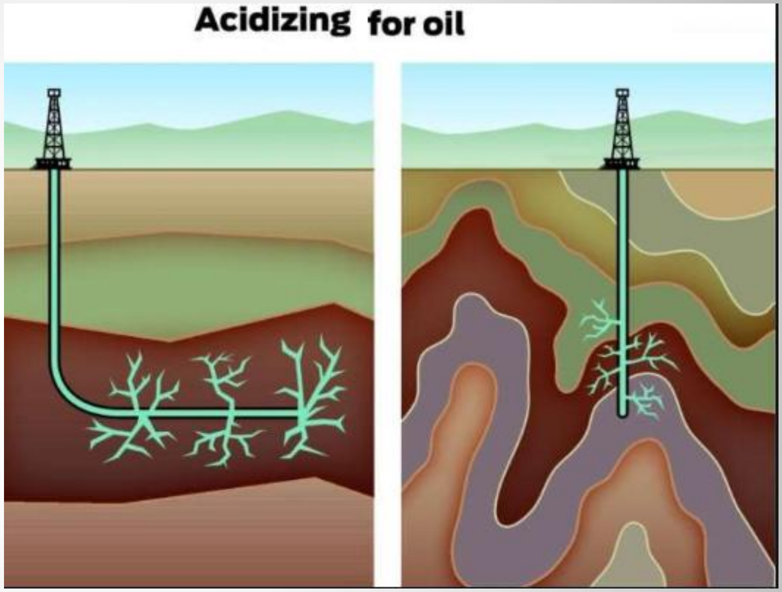
- In matrix acidizing, the intent is to improve or to restore the permeability of the region very near the wellbore (a radius of 8 to permeability of the region very near the wellbore (a radius of 8 to 24 in. [20.3 to 61 cm]) without fracturing the producing formation. The increase in permeability will decrease the pressure drop associated with the production or the injection of fluids by enlargement of the pore throats or by removal of formation permeability damage created by drilling or completion fluids. The permeability damage created by drilling or completion fluids. The amount of production increase that is created by a matrix acid job will depend on the reservoir pressure and whether the formation permeability next to the wellbore is damaged.



- The length of an acidized fracture is limited, however, by the rate at which acid is spent on the carbonate and by the increasing fluid leak off. The acid-etched fracture will extend only as far as unspent acid has penetrated. The acid reactivity is a function of several variables, the most important of which are temperature and the area/volume ratio (i.e., the ratio of the area of reactive formation in the matrix or fracture to the volume of acid in contact with that area). The higher this ratio (more surface area), the faster the acid will be spent (penetration of live acid is reduced). In the formation matrix of a low-permeability carbonate, the area/volume ratio can be over 30,000: 1. In a hydraulically created fracture, the value will be about 100: 1. This ratio is a description of the formation or fracture conditions, and very little can be done to alter it. Fluid lost from the acid in the fracture also decreases the possible fracture length because less fluid is left to extend the possible fracture length because less fluid is left to extend the fracture. Leak off from the acid volume in the main fracture is increased by the reaction of the acid, which increases the permeability of the leak off zones.

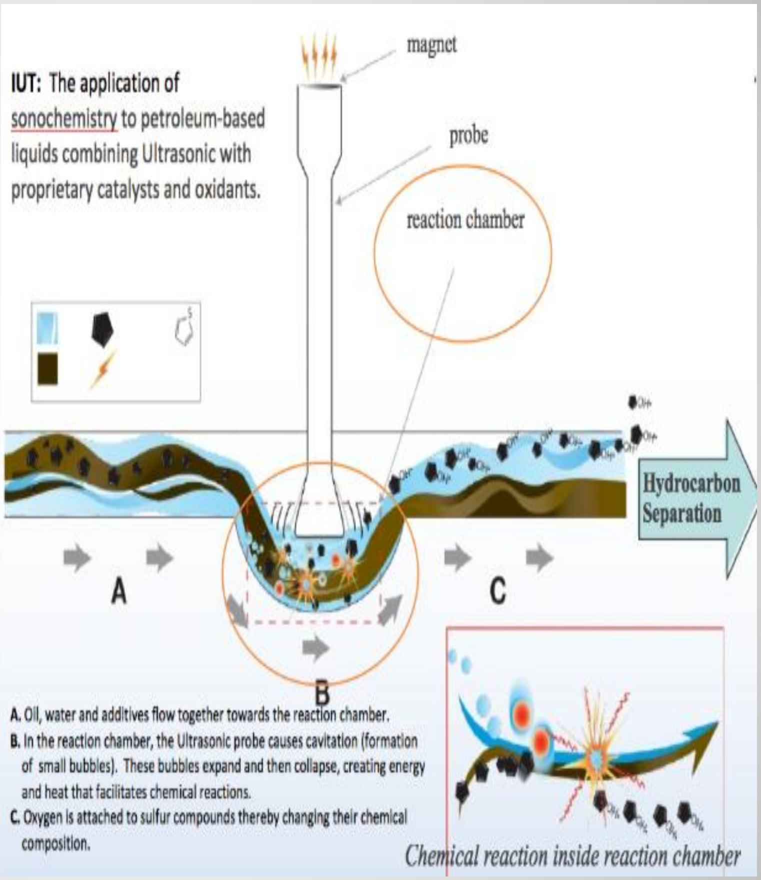
FRACTURE ACIDIZING

- Fracture acidizing is a hydraulic fracturing treatment for carbonate formations in which acid-etched channels serve as very-high-conductivity flow paths along the face of the fracture. HC1 of 15 to 28% strength is used in acid fracturing at volumes of 100 to 500 gal [1.24 to 6.2 m3] of acid per foot[meter] of producing formation. Hydraulic fracturing actually breaks the producing formation. Hydraulic fracturing actually breaks the formation with pump- and hydrostatically produced pressures. The pressure pans the formation and produces a crack along which the pressure pans the formation and produces a crack along which the acid flows. The acid reacts with the carbonate, removes part of this reactive rock, and leaves channels along the face of the crack. For the channels to form, the formation must be limestone, dolomite, or chalk with a total carbonate content of at least 60%. Productivity increases that are available from acid fracturing depend on many of the same conditions as water and propant fracturing. These conditions are permeability, pressure, viscosity of produced fluid, and length and conductivity of the fracture. In undamaged, low-permeability formations with equal reservoir pressures, fracturing will increase production far more than pressures, fracturing will increase production far more than matrix acidizing. Higher-viscosity fluids (such a soil) can flow much more easily down the high-conductivity acidizing fracture than through a high-permeability matrix



CAVITATION

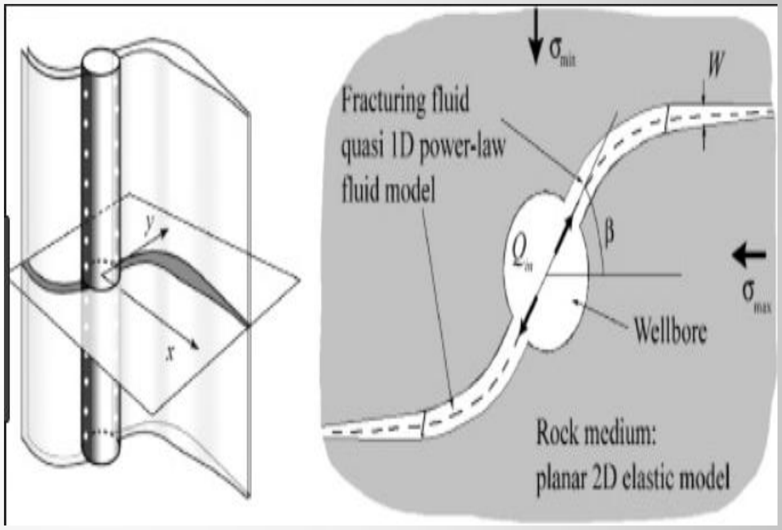
- when the water accelerate to pass through comers of the nozzle, the pressure may drop below the vapor pressure. This may cause vapor bubbles to form. as the flow moves into a larger area, the pressure recovers to a certain degree. This increases the pressure above the vapor pressure, causing the vapor bubbles to collapse or implode. The shock waves may be extremely high and cause additional erosion and tension effect.



- The net forces that affect to drive jetting nozzle forward can be derived from three main mechanisms ; under pressure force , jetting force and ejector force . The main mechanism is jetting force mechanism

NEAR WELLBORE RESTRICTION

Fracture Design Engineering computations always precede a fracturing treatment. These consist of calculation of fluid volume and viscosity, injection rate, weight of proppant, volumes of different phases of the job (prepad, pad, slurry, and displacement), surface and bottom-hole injection pressure, hydraulic horsepower required at the surface, and the mechanical equipment needed for this. A very important part of fracture design is determination of the fluid volume required to create a fracture with a given length. A hydraulic fracture is usually identified by three dimensions: length, width, and height (Fig. 5). Fracture length itself has two components: created and propped. Created length is the distance between the wellbore and farthest point into the formation. Propped length is the distance between the wellbore and farthest point where proppant has travelled inside the fracture. Fracture width is the separation between the two faces of the fracture. Its value is largest at the wellbore and tapers toward the tip of the fracture. Fracture height is the distance between the top and bottom of the fracture.



MECHANICS OF HYDRAULIC FRACTURING

- Fluid injection at high pressures and rates causes initiation and extension of hydraulic fractures. The pressure required for fracture initiation depends on the values of the three in-situ principal stresses, formation mechanical properties, and the formation's tensile strength. The pressure required for fracture extension is dominantly controlled by the least in-situ principal stress. Fracture orientation is perpendicular to the direction of the same principal stress. During fluid injection, the fluid pressure inside the fracture is higher than the least in-situ principal stress, and this keeps the fracture open. But after the injection stops and pressure is allowed to drop, the fracture begins to close. To keep the fracture open and conductive (permeable) after the treatment, a propant is mixed with the fluid and injected inside the fracture to keep it open during production operations. Fig. 3 shows a fracturing chart with various stages of the treatment marked on it. The vast majority of fracturing treatments use water as the base fluid and add to it various chemicals to give it specific physical and chemical properties. Each fracturing job begins with injection of a prepaid, which usually consists of a mixture of mid- to low-strength acid and water. This is followed by a "pad," which is a mixture of water and a viscosities or friction reducer (usually a polymer). This is then followed by the "slurry" which is a mixture of propant and the fracturing fluid.

SAND CONTROL MANAGEMENT

- When oil is produced from relatively weak reservoir rocks, small particles and sand grains
- are dislodged and carried along with the flow. This sand production can create erosion in
- flow lines and other equipment. Sand management can be considered as a key issues in
- field development in most of world's oil and gas fields. Sand control management can be
- counted as an activity which shares risks (safety, environmental, process and cost) of
- producing sand to the surface vs. the risks of trying to keep it down in the reservoir using
- different mechanical or chemical control techniques.

FORMATION COLLAPSE

- In loosely consolidated or weakly cemented formations, the severe pressure drop that occurs around a
- wellbore can cause the formation to collapse. When this occurs, the pore structure is altered and the
- permeability is reduced, causing skin damage around the wellbore. To prevent this, a small
- hydraulic fracture treatment can be performed early in the life of the well. The fracture treatment will
- help minimize the pressure gradients and reduce the chance of formation collapse around the wellbore.
- As the pressure is depleted throughout the reservoir, the overburden pressure caused by the overlying
- rock tends to compress the formation. This overburden pressure can also alter the pore structure and
- reduce the permeability. The degree of severity is a function of the formation compressibility.

CHEMICAL SOLUTIONS

- Using various techniques to incorporate chemical treatments into the formations being drilled can reduce the number of casing strings, which is one of the primary goals of the mono well. During the drilling of a mono bore, new well-construction methods can be employed when encountering low mechanical - strength formations, unconsolidated weak zones, or abnormal geo pressure profiles that will allow extending the casing length.

- *Thank you*