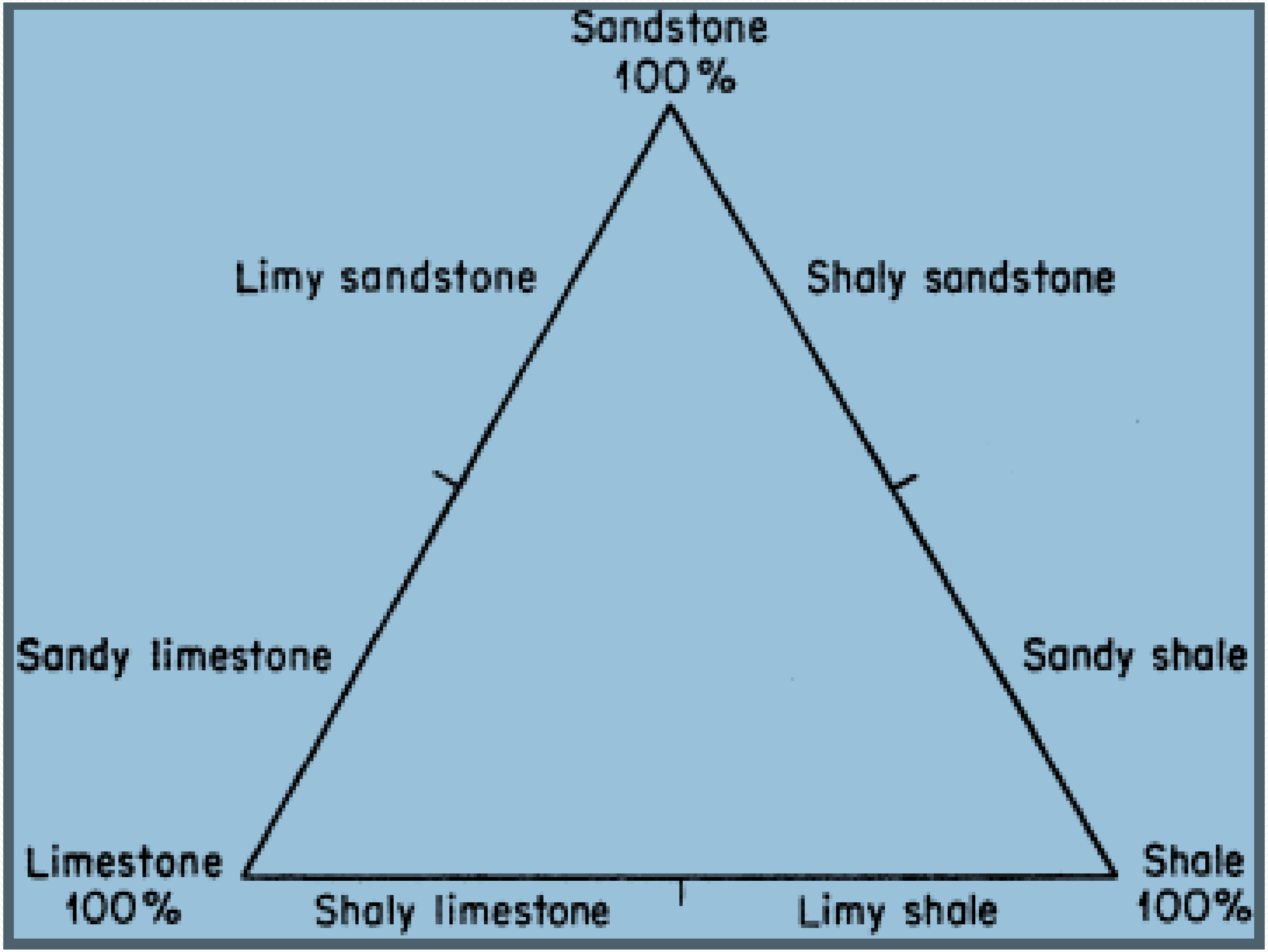
NATURALLY FRACTURED RESERVOIRS

- Naturally fractured reservoirs represent more than 50% of reservoirs
- and contribute in a large extent to the worldwide production of oil and
- gas. These highly heterogeneous reservoirs possess a complex network of
- several fracture families with different spatial distribution and conductivity.
- Performing a reservoir characterization study on these naturally fractured
- systems is a challenging task because they present an extreme
- property contrast between the two domains it comprises: rock matrix and
- fractures.
- Naturally fractured reservoirs are found in many depositional environments,
- including:
- • Carbonates
- • Shales
- • Sandstones


Sandstone
100 %
Limy sandstone
Shaly sandstone
Sandy limestone
Sandy shale
Limestone
100 %
Shaly limestone
Limy shale
Shale
100%

- three sedimentary rocks are so common in reservoirs that it is convenient to think of all sedimentary rocks as being composed of carbonates , shales , and sandstones. the relationship of these common rock materials. indicates the gradation from one type of rock to another, Which is commonly used with hydrocarbon field . A significant percentage of oil and gas reserves (more than 60% of the
- world's proven oil reserves and 40% of the world's gas reserves) are trapped in fractured carbonate reservoirs.

- **Carbonate reservoirs** represent a broader range of hydrocarbon productivity than sandstone reservoirs. The most common production rates come from carbonate reservoirs . Many carbonate reservoirs will not yield oil and gas at all unless they are artificially fractured.
- These reservoirs, because of their complexity and heterogeneity,
- are considered extremely challenging in Most carbonate reservoirs are naturally fractured and contain fractures that can range from Isolated microscopic fissures to kilometer-wide collections called fractures warms or corridors. These fractures create complex paths for fluid movement, which impact reservoir characterization and, ultimately, production performance and total recovery.

- Knowledge the exact position of these fractures is essential to produce reliable results from reservoir simulation studies.
- There are several important factors to note when considering fractures in carbonated reservoirs:

- 1-Fractures of the same orientation and direction.
- 2-Density and opening of the fractures.
- 3-Size of fractures in both horizontally and verticality end.

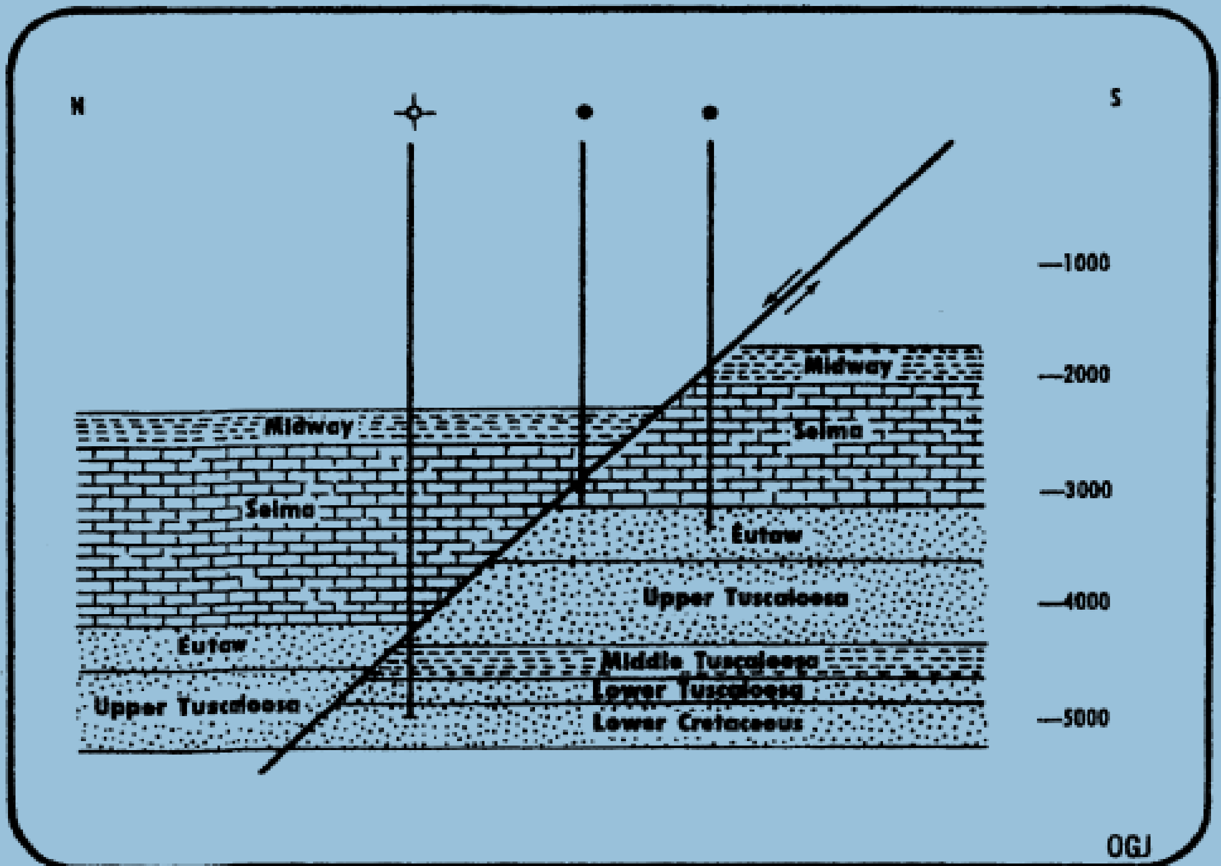
- Carbonates are limestones, dolomites, and .
- Carbonate reservoir rocks can be divided in to the following lithologic types:
- Ooliticl imestone
- Limestone
- Chalk
- Dolomitic limestone
- Dolomite

- The physical properties of oolitic limestone are largely determined by
- the depositional environment. The remaining carbonate rocks are largely finely crystalline, and their physical properties depend greatly on such processes as deformation and solution after deposition. A limestone has
- little resistance to tension, and when it is subjected to tension forces, fractures develop.
- The subsequent development of fractures allows subsurface water to percolate through these fractures and consequently subject the carbonate material to the processes of secondary solution and deposition.
- An example of a carbonate reservoir is the Selma fractured chalk in Gilbertown oil field, Alabama

. The Figure shows a schematic cross section of Gilbertown field. Aguilera (1987) indicated that no matrix porosity was found in the chalk and that fracture porosity was associated with the fault zone. The fracture porosity provided a secondary trap for oil that migrated from lower Eutaw sands. Production from the Selma chalk comes

- only from wells located in the down-thrown side near the fault.
- the dry well encountered a complete section
- of the Selma chalk but was far from the fault and consequently did not penetrate any fracture. The middle well near the fault produced oil from the fracture Selma chalk. Finally, the well to the right of the fault produced
- oil from Eutaw sands, but not from the Selma chalk.

Gilbertown field



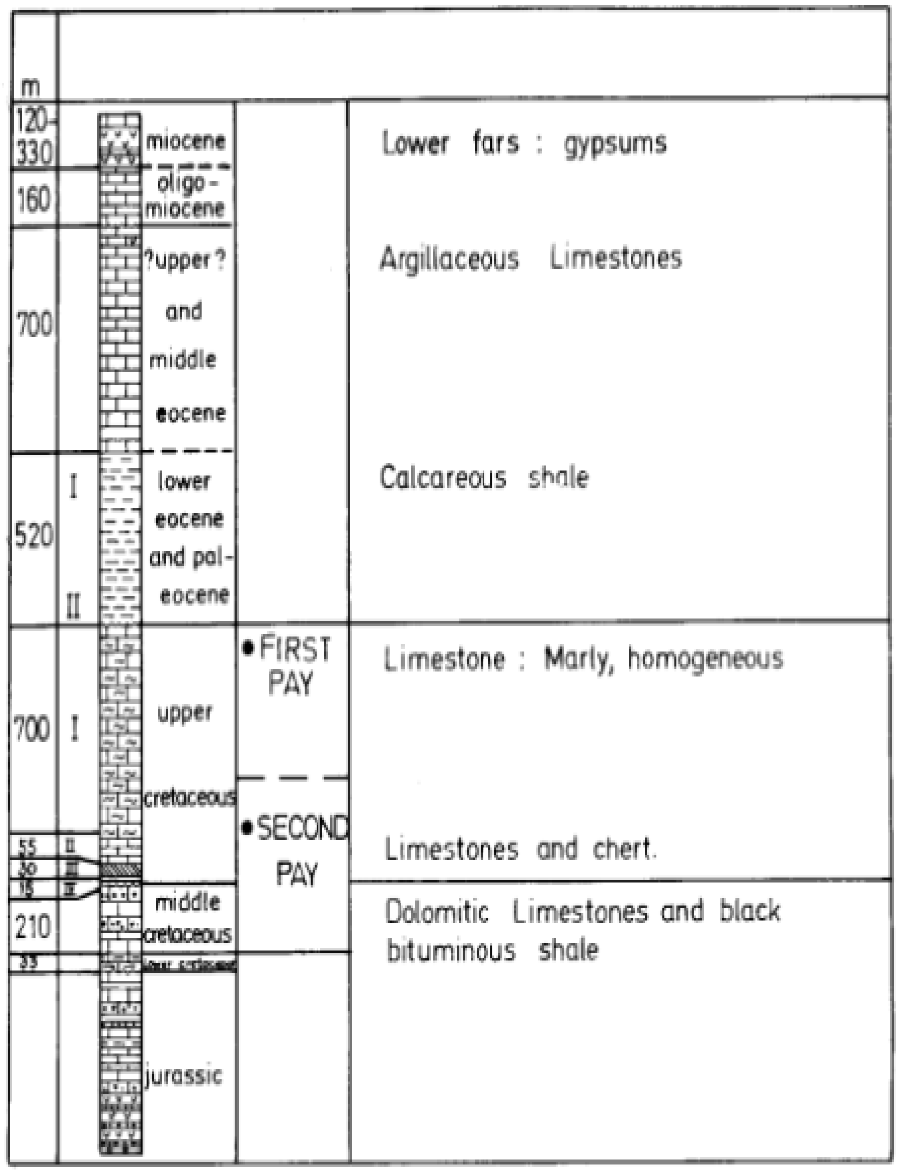
- The Ain Zalah carbonate oil reservoir in Iraq is extremely tight and has very low porosity. However, because of the presence of fractures, the reservoir can produce at high rates during limited periods. It is postulated that hydrocarbon fluid entered the reservoir by upward migration along fractures from a deeper zone, perhaps in the middle of the Cretaceous or during the Jurassic period. Because the formation had a high degree of fracturing, it was proposed that the pay zones could be drained by two to three wells.

- . Ain Zalah field, Iraq6
- This oilfield exists today only as a result of a complex fracture system which provides
- both the porosity and permeability essential for oil production. The country rocks
- are otherwise low in porosity and entirely without permeability.
- The field is located some 60 miles northwest of Mosul in northern Iraq (figure 3.1)
- on a surface anticline 12 miles long and 3 miles wide (figure 3.2).
- Although the field was first discovered in 1939, development did not follow until
- 1947, and full production (27,000 barrels of oil per day) was not reached
- before 1952.

- Prior to 1951 total production was obtained from 13 wells drilled into fractured marly
- limestones of upper Cretaceous age, named the First Pay Reservoir. Deeper drilling
- between 1949 and 1950 proved a lower reservoir in porous and fractured limestones
- of lower-middle Cretaceous age, then named the Second Pay Reservoir, separated
- from the first by approximately 600m of seemingly impermeable strata. Detailed
- testing, however, immediately indicated a connection between these previously
- assumed separate reservoirs, an explanation for which was found in the presence of
- rare, fine, feeder fissures.
- A typical well section (figure 3.3.) illustrates the lithology and stratigraphy of the
- two pay zones and their relation to both over and underlying strata. The Ain Zalah
- oil most certainly originated in the middle Cretaceous and/or Jurassic horizons, but
- did not migrate to the higher reservoirs until after the fracturing had taken place.
- Although both pay zones are essentially fractured reservoirs,

- the Second Pay Reservoir is much thicker than the First Pay Reservoir, comprising a more
- heterogeneous lithology and a greater diversity of fractures. Despite the
- complexity of the fracture networks, three main types have been recognized, In their relative order of importance for oil production they are:
- 1. Fracture networks filled or partially filled with calcite (found only below the base
- Paleocene unconformity) and, although apparently multi-directional,
- they comprise three classes:
- a. those at 30"-35" to the long axis of a core,
- b. those vertical or near vertical, and
- c. those at 65"-70" to the long axis of a core.
- The density of these fractures vanes between 6- 12 per foot (brecciating the rock
- in places), and their width varies from 0.1- 1.8 mm.
- 2. Fractures filled or partially filled with calcite and silica (found mainly in the
- Second Pay Reservoir), evidencing multiphased mineralization.
- 3. Open fractures/joints (found in both pay reservoirs), generally several sets at
- different dip and strike angles and varying in width from 0.1-0.2mm.

- In addition to recognizing these types, drilling has further shown that both the total
- amount of fractures of Types 1 and 2 and the number of fracture phases increase with
- age, whereas Type 3 is more or less evenly distributed throughout the column.
- The origin of these fractures is explained by two phases of structural deformation
- which has selectively shattered the more brittle strata. The earliest period
- occurred between the upper Cretaceous and the early Paleocene when the
- First Pay Reservoir was gently uplifted and exposed to sub-aerial erosion.
- The highest frequency of mineralized fractures (Types 1 and 2) is found
- in those areas of maximum Cretaceous-Paleocene uplift. A later period
- 115
- of uplift occurred between the upper Eocene and basal Miocene; but this
- was mild and the rocks remained relatively undisturbed. The latest and
- most significant movements which uplifted the present day anticline
- occurred between the Miocene and the Pliocene, and are believed to have
- caused the third type, or open joints.
- In Ain Zalah the porosity of the unfractured rock matrix may vary between
- 0- ll%, but the permeability is too small to record. Production, therefore, depends
- entirely on the fracture networks, a fact which is confirmed by drilling operations.
- Where equivalent unfractured rocks are encountered, experimental dataZ has established that a single fracture lmm in width can produce at the rate of 7.000- 1O.OOO
barrels of oil per day.


m
120-
330
miocene
160
oligo-
miocene
700
?upper?
and
middle
eocene
520
I
II
lower
eocene
and pal-
eocene
700
I
upper
cretaceous
55
30
15
210
middle
cretaceous
35
jurassic
FIRST
PAY
SECOND
PAY
Lower fars : gypsums
Argillaceous Limestones
Calcareous shale
Limestone : Marly, homogeneous
Limestones and chert.
Dolomitic Limestones and black
bituminous shale