Deliverability of Gas condensate "sandstone reservoir"Khabour Fm. Akkas Field,western Iraq

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Abstract

The Khabour Fm. (ordovicain) presents a prospective target for exploration and developiment, as it certains **"Gas Condensate"** light gravity, low sulfur oil, and sweet gas as proven by Akkas field, in the western desert of Iraq .

Gas- condensate project is in depth,hot,low permeability reservoir in the upper K1,K3,K5 sandstone members ,it's well known that the deliverability of gas-condensate wells can be improved by the formation of acondensate bank once a bottomhole pressure drope below the dewpoint. Improving deliverability can be improved by use the techniques as,Fracturing andchemical treatment.

The Khabour formation total thickness is 1913m,represntaed by elastic series mainly shaly intercalated with sandstone beds in the lower part and by well developed sandstone beds in the upper part, In Akk-1 which is subdivided into eight members according to sand /shale ratio, the need for accurate estimate for reservoir properties of these member extends to the whole life cycle of a reservoir; detailed

simulation and planning of future production which including for

discovery , appraisal , planning , development and production from Akkas field.

Introduction

The older and the deeper tight reservoirs are in the Akkas field, Khabour Fm. (Ordovician) presents a prospective target for exploration and development, as it certain **"Gas Condensate"** light gravity, low sulfur oil, and sweet gas as proven by Akkas field, in the western desert of Iraq .

The Fundamental element to effective production of gas from this type of low –pearmeability sandstone is understanding their in situ petrophyiscal properties.The present paper follows in the footsteps of suday and attempts to expand the litholoigic range of low-permeability sandstone members.

The first Gas condensate discovery in Iraq is Akkas field in iraq western desert. Akkas field was discovered in 1993 by deepest well Akkas-1 and was subsequently appraised with five wells, have been drilled on the main structure in different penetrated of members of Khabour formation. wells (Akk-1,2,3,4) tested Condesate gas from oldest sequence (Ordoviain) Khabour formation.

The discovery well and three appraisal wells were side tracked with horizontal lateral in the Khabour formation (Ordovician). The Khabour formation is the oldest formation of the lower Paleozoic strata of Iraq, which is the primary gas reservoir a in Akkas field,which is may provide significant gas reserves in the 21 st century . The simulation and planning of future production which including for discovery , appraisal , planning , development and production .

Geological And Structural Framework

The Paleozoic succession is incomplete due to significant hiatuses, NO Permian and Mesozoic section,erostion of 1.250 km.of sediments during Hercyninen events in Akkas field. . The Paleozoic sequences has been focused in the shallow depth compared with eastern Iraq.The crystalline basement and Cambrian rocks are neither cropped out drilled by any wells. Precambrain basement at depth of probably between 4 and 6 km (Lovelock ,1984) , lies at depth about (5.5 -7) Km.,Nager 1999.

In general Kabour Formation is characterized by series of transgression" 2nd rapid Middle and Late Ordovician" while regressions in Middle and Late Ordovician.

The formation was defined by Wetzel (1950) in Bellen et al. (1959) as 800 m of white and grey quartizitic sandstone inter bedded with micaeous silty shale at the type locality near Sinat, North West of Amadia in the Northern thurst zone of Iraq. The well Akkas -1 was penetrated Khabour formation as subsurface in western Iraq. The Akkas field regressive sandstone on top of K1 Member of the Khabour Fm is the main gas and condensate reservoir, which is enhanced by fractures .The lower contact of the formation was not reached in drilled well Akk-1 ,while the formation is unconformably overlied by Akkas formation (Silurian), As for Hot shales they are acting as top seal rocks and hydrocarbon charge for Khabour sandstone members.

Geographic And Tectonic Location

Akkas field is located geographically in Anbar province at western of Iraq, and tectonic to Northern extension Hail- Rutbah Arch in western of Iraq desert which is apart of the stable shelf of

Nubio- Arabian shield, within the stable shelf zone of Arabain Plate, which is comprises abroad dome - like structure bounded to NE keystone graben formed by conjugate set of en-echelon normal fault and it's structure is accompanied by small fault truncated. At Northern end by Anah west graben Anah –Fatha fault, E-W trending of Anah graben (Fig -1).

Akkas field is an structural trap formed by a faulted anticline closure of the Ordovician Khabour formation over a basement rocks. Akk-1, Akk-2 is located on North East flanks of Akkas structure, Akk-3,Akk-4 near crest and Akk-5,Akk-6 is locate in NW end &South East flank of the structure respectively.

Methodology And Samples

Specific sedimentology of sandstone under examination was defined using classical; core description (core #11 to 24), grain size, texture and fabric, sedimentary structure…etc. petrographic analysis was performed on approximately (135) sample using routine optical microscopy on carbonate and feldspar staining thin section, some of thin section were point counted to quantity grain and Petrophysical properties were obtained from exploration studies AL-Rabaii in AL-sammari et al.1994 and AL–Quwaizy, M. 1997. wire line logging was not carried out below 3769 to total depth (4238) m. In well AKK-1, Stratigraphic parameters in sixth wells.

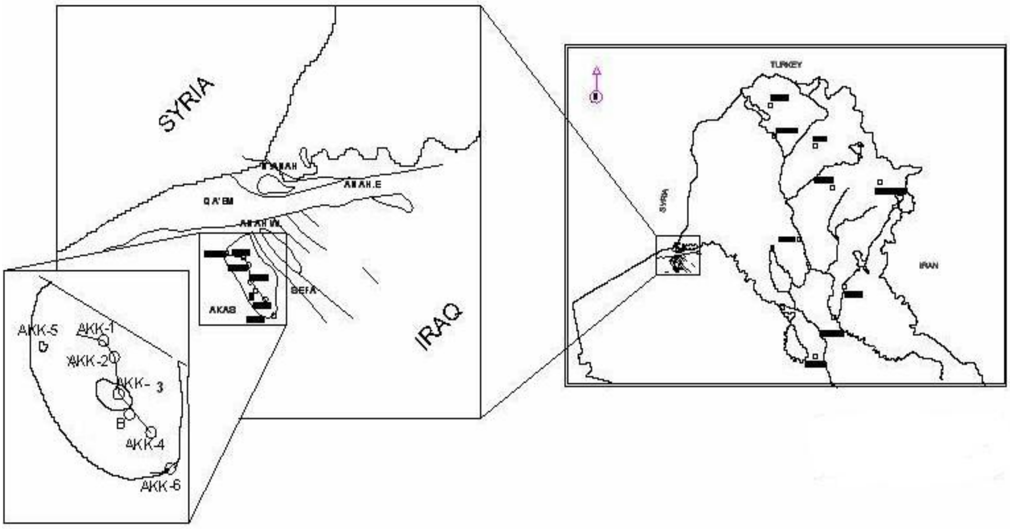

Fig .(1) Location Map Akkas Feild West Iraq

Khabour Members

The "low permeability" or "tight gas" designation of Khabour members are resulted due to difference in litholoigic properties,log facies,petrofacies control which are considered as variations in the interwells of Akkas field.

Most previous studies are subdivided the Khabour formation into four member (e.g. M.AL-Rubaii, in AL-Sammarai et al., 1994; AL-Quwaizy,1997), Al-Hadidy ,A. (2007) subdivided into seven informal (K1 to K7) members, also in this study subdived into subreservoir beds of

K1member, all these on the basis of lithofacies, sediment characteristics(such as grain size, color, sediment structure, sand/shale ratio) and palynology. Fig.(2,3,4,5);Table-1, Plate-1.

These members is an attractive gas exploration target as it is favorablay, positioned with respect to source and seal unit.

This package appear to contain two maximum flooding surfaces (MFS) or maximum flooding intervals (MFI) : one in the K4 to K7 member and a second in the K2 member Fig. (3,4,5).

These members divided into multiple reservoirs of sandstone which initiated rapid Marine transgression and followed by a regression, in addition high frequency relative sea level change .The description as below denoted from younger K1 to older K7.

K1 Member " Upper Sandstone"

Khabour K1, the"upper sandstone"member,was encountered in Akkas-1 between 2,327 and 2,375m(7,633-7,790ft),and is 48m (157ft) thick

K1 represent main reservoir in khabour formation Akkas field . K1 Member can be divided vertically into three zone according to sandstone maturity (shale – sand rich)plate-1., which extends laterally in 6 wells Akkas.

upper K1 Bed:

It composed the upper 17 m. of K1, which is quartizite with very thin shale streaks and, It extends laterally in all six wells .

middle K1 bed:

It composed the middle 10-16 m. of K1, as clean quartizite bounded by two shale lamina, which is best reservoir for horizontal drilling.

Lower K1 bed:

It composed the upper 16 - 25m. of K1, as quartizite with very streaks shale streak mor than zone1, It extends laterally in all six wells this zone represent lower part of K1 member which, more shaly so reservoir quality is low .

K1 represent clean sand which increase (sand-rich) to NW of Akkas field (Akk-1,5) respectively increase shale(shale-rich) argillicious sandstone to well (Akk-3,4), as well as to bottom of members to zone3. K1 sandstone white–gray intercalation with shale streaks, this massive, Hommoky Cross-Lamination, some Biourbation, at 2388.42 erositional surface, C # 11 sandstone boulder are found. petrograghic studies of K1 sandstone is Quartzarenite in major and Subarkoss .Most sandstone of K1 are clean, moderately well to modertaly sorated that exhibit limited varation in detrital composition withen and between Akkas wells, Important feature is microfracture open and healed with frequency vertical, horizontal and inclined which become main driver of productivity.

K2 Member " Upper Shale With Thin Sandstone"

Khabour K2, the "upper thick shale "member, was represents the uppermore shale bed of late Ordovician encountered in Akkas-1 between 2,375and 2,500m (7,790-8,282ft), and is 150m(492ft) thick It extends laterally in all six wells K2 compose of black shale may be as source rock intercalation with white sand streaks, contain Falser structure and Bioturbated shale ,which appear in high GR reading correlative with low GR in K1.

K3 Member " Interbeded Shale And Sandstone "

Khabour K3, The "Interbeded shale and sandstone" member, was encountered in Akkas-1 between 2,500 and 2,675m(8,202-8,774ft) and is 150m (492ft) thick this member represent another reservoir unit but less quality than K1 due to shaleness.

It represent of gray compact silty shale ,and penetrated completely in (AKK-1,2,3) and partially in (AKK-4,5,6).Fig 2,3,4,. K3 shale represent fissile black shale ,white-gray-Massive Micaceous sandstone with siltstone.

K4 Member " Middle Shale With Thin Sandstone "

K4 represent inter mediate thickness ,and similar lithology to K2 members and intercalation with micaceous quartzwake sandstone. K4 penetrated completely in (AKK-1,2,3) and not penetrated in (AKK-4,5,6). Fig.(2,3,4). Khabour K4,the"middle shale"member, was encountered in Akkas-1 between 2.675 and 3,025m (8,774-9,922ft), and is 350m(1,148ft) thick.

K5 Member " Lower Sandstone With Thin Shale"

Khabour K5"lower thick sandstone" member was encountered in Akkas-1 between 3035m(9,957-19,578ft) ,and is 200m (656ft) thick (Fig.6).K5 represent another less important reservoir respectively to K1. K5 sandstone fine –medium grains white-light gray massive intercalated with black band shale and, the gravel was seen at3171.72m.C #19 by (Al-Quaizy,1999), which represent regressive phase. penetrated completely in (AKK-1) and partially in (AKK-2,) and not penetrated(Akk-4,5,6) .Fig. (2,3,4) .

K6 " Intercalated Shale, Sandstone And Siltstone "

The Khabour K6 "intercalated shale and sandstone" member was in Akkas-1 between 3125 and 3,610m (10,578-11,841ft),and is 385m(1,263ft) thick .It represent transition members between K5 and K7,compose white-gray,fine grains styolitic sandstone with gray laminated black gray shale. The overlying Khabour K6 and K5 members in Akkas-1 probably correlate to the Middle Ordovician (Liandeillo=Darriwillin) Kahfah member of the Qasim Formation in Saudi Arabia (Vaslet et al,1987,1994).

The Kahfah member is divided in to lower and upper units, which are separated by a disconformity, and the two units may correlate to the Khabour K6 and K5 members. penetrated completely in (AKK-1) and not penetrated(Akk-2,3,4,5,6) . Fig.(2,3,4) .

K7, The "Lower Thick Shale" Member "

Khabour K7,the "lower thick shale"member ,was encountered in Akkas-1 Between 3.602m and total depth at 4.238m(11.817-13.901ft), and is greater than 628m(2.060ft) thick.This basal unit consists of homogeneous black shales, commonly fissile with dominant mica and irregular pyrite blotches. The great thickness represent high phase of the first transgression in Middle Ordovician, which is pyrite content and lack of bioturbation may reflect deposition in reducing euxinic conditions. This interpretation of the depositional environment is supported by these studys of Baban(1996). K7 penetrated completely in (AKK-1) and not penetrated(Akk-2,3,4,5,6) . Fig.(2,3,4) . Table .(1,2).

The Khabour K7 member, on the basis of its probable " Lianvirn" age. The basal of K7 member may represent Early Ordovician from depth (4132 - 4238)m. Core/24,25 personal comm. Baban(2008).

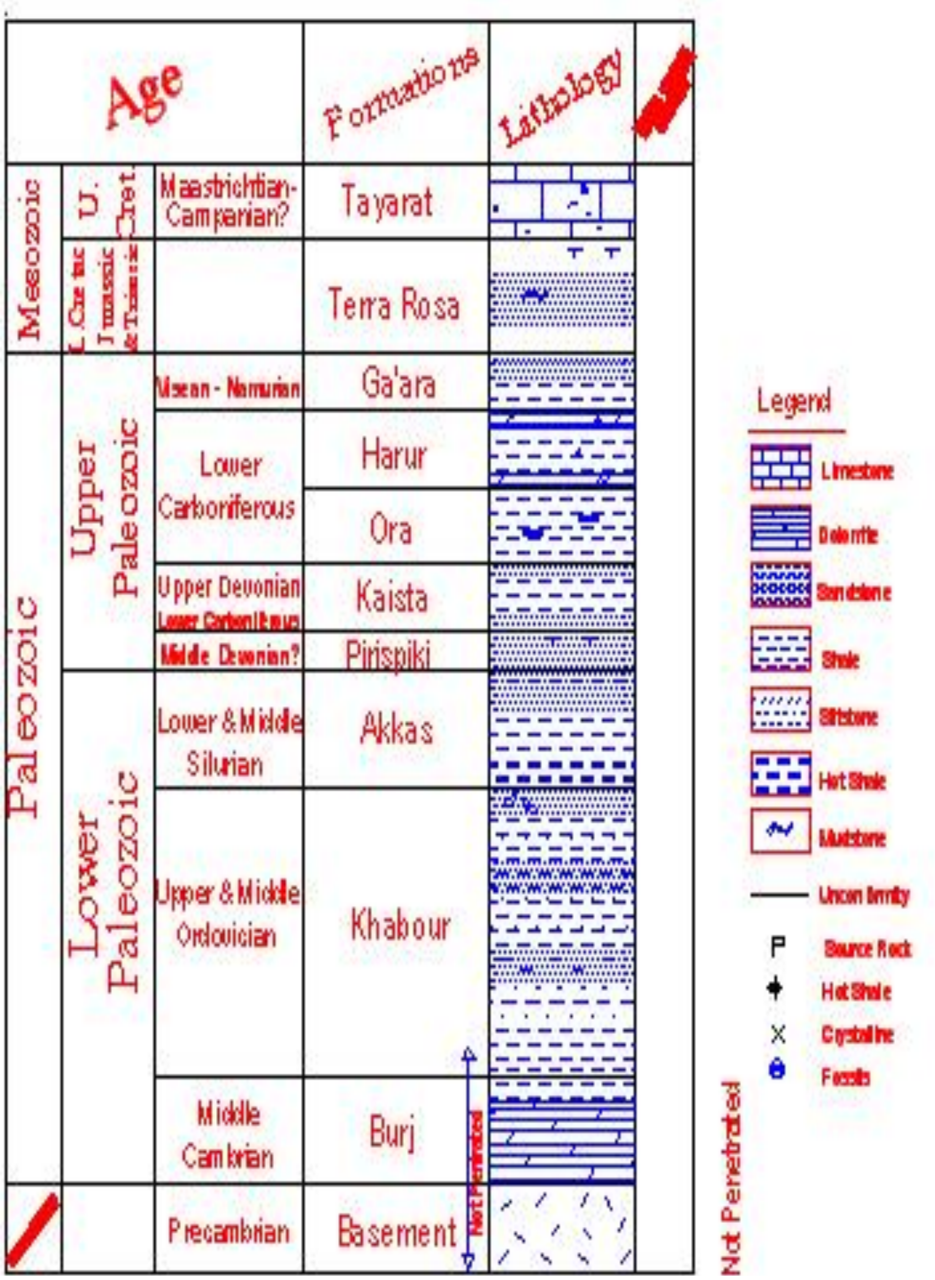

Fig.(2) Litholgic Column & Sedimentary Core Of AKKAS – 1 , West Iraq

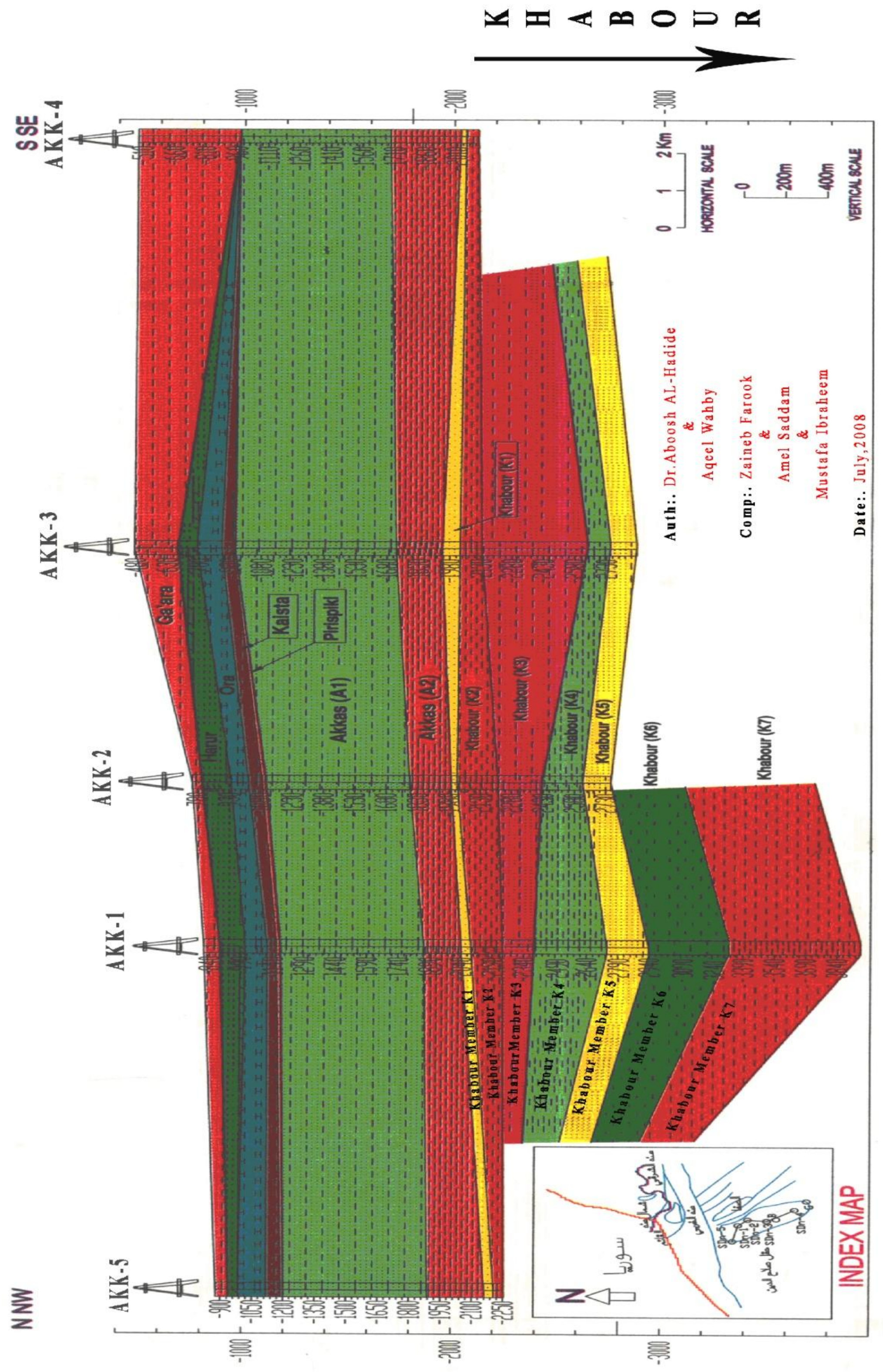

Fig.(3) Strtigrafic Cross Section Through 5 AKKAS Wells

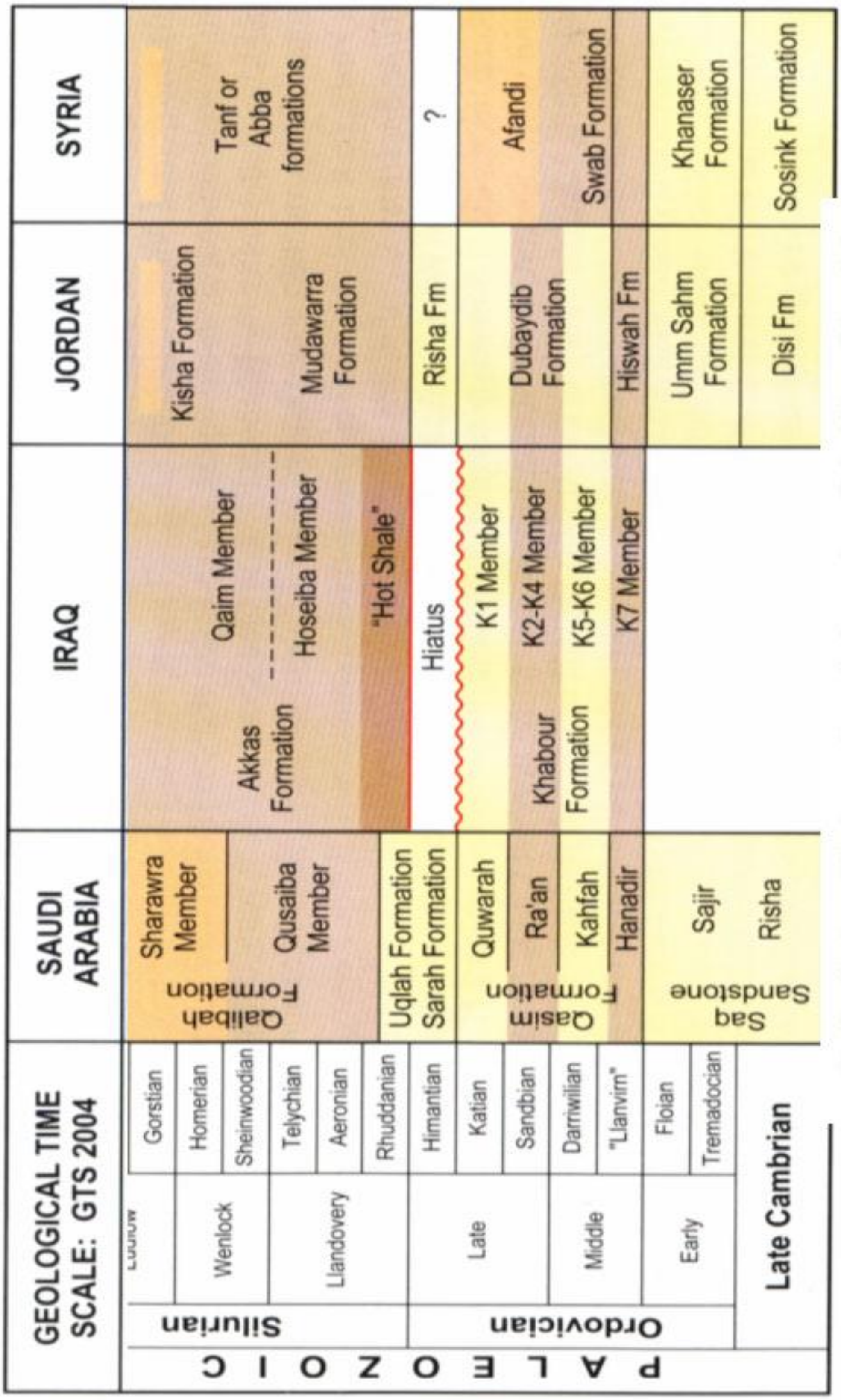

Fig.(4) Khabour Members , Core Lation and Equivalent in Arebian Plate

Table(1) Khbour Member & Lithofacies , Depositional Setting

AGE	Formation	Rock Unit	Code	Inerval Thickness (m.)	Lithologic Description	Depositional Setting	Package Sequence		Hydrocarbon Occurren
LOWER ORDOVICIAN	KHABOUR	Upper thick Sandstone " Gas Sandstone "	K1	40 - 65	Sandstone ,white to grey ,dense fine - medium grains ,Structurless Hummoky Cross Lamination type ,is Quantzarenite ,Quantz wacke fractured (open + heald) with shale ,gy ,Laminted . @ c# 11,2338.42 congl,erositional,	Siliciclastic plat form " Shallow Ramp " Shallow Subtidal to coostal , Tidal flat .	Progradational 1	Weak	Good Gas Show
		Upper thick Shale	K2	90 - 100	Shale ,grey ,darkgrey ,Laminted and micaceous, Silty ,with thin beds of Sandstone ,white dense , fine - medium ,deformed fining up ward .	Deep Ramp	Retrogradational 2	Weak	Source
		Interbeded Shale and Sandstone	K3	350 - 400	Shale ,grey ,darkgrey ,Laminted ,Pyritic ,with Siltston ,and Sandstone ,white - grey ,fine - grained Silica cement .	Shallow Ramp Wave Agitated	Aggradational/Retrograd 3	Weak	Weak Gas Show + Source
		Middle thick Shale	K4	180 - 210	As unite (K2) ,But less facture .	Deep Ramp Shallow Basine	Retrogradat 4	Weak	Very Weak Gas Show
		Lower thick Sandstone	K5	200 - 225	Sandstone ,gy ,wht ,fine - medium grains , Sub angular - Sub rounded moderly Sorted . *gravel @ c#19,317,72m*	Shallow Ramp ,Costal Subtidal to Tidal Flat	progradat 5	Weak	Weak Gas Show
		Interculation Shale, Sandstone and Siltstone	K6	375 - 400	Shalei dark grey ,Laminated silty ,with Sands- tone ,white massive ,fine - medium grain stylolite ,quartz arenit ,Qzbarkose W/ fine Siltstone strealc .	Middle Ramp	Aggradational Retrogradational 6	Weak	Non Reser Uior
		Low thick Shale	K7	650 - 700	Shale ,black ,fissile pyritic ,micacea ,fractured Homegen, graptolite .	Deep Ramp Deep Marine	Retrograd 7		

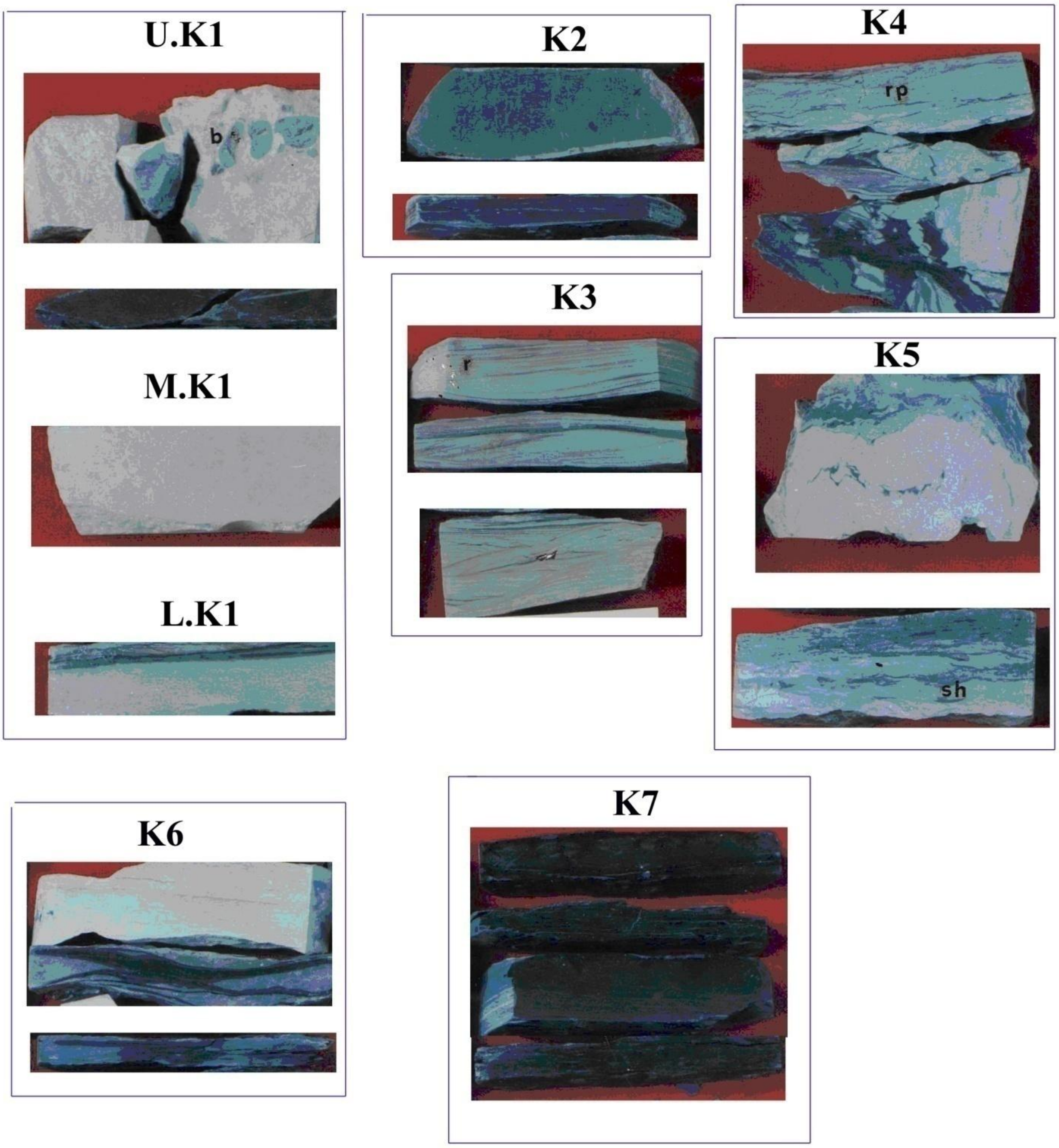

Plate-1: Khabour Members facies

Khabour Members Stratigraphy Correlative

The **K1 member** is correlated to the Quwarah Member of the Qasim Formation and may, in upper part,not appear in Iraq (Akkas field) ,be coeval to the glaciogenic Sarah and post-glacial Uqlah formation of Saudi Arabia(Vaslet et al1987;Vaslet,1990;Senalp and Senalp,M.andAL-Duaiji,(2001) Fig.(5).K1is correlated to the upper part of the Afandi Formation of Syria (Y.Kauskas and S.Talli ,unpublished Syrian Petroleum Company report in Lababidi and Hamdan,1985) and the Risha Formation of Jordan (Andrews et al.,1991; Aqrawi, 1998a.b) Fig.(4,5).

The K1 to K3 members may correlate to the Quwarah Member of the Qasim Formation and may,in part,be to the glaciogenic Sarah and post-glacial Uqlah formation of Saudi Arabia Vaslet et al.,1987, Vaslet, 1990, Janjou et al.,1997a,b, Senalp and AL - Duaiji, (2001). K1 to K3 may also correlate to the upper part of the Afandi Formation of Syria (T.V.Yankauskas and S.Talli, unpublished Syrian Petroleum Company report in Lababidi and Hamdan,1985)and the Risha Formation of Jordan ,Aqrawi,(1998 a,b)

The K2- K4 members is correlated to the Raan Shale Member of the Qasim Formation of Saudi – Arabia (Vaslet et al.,1987,Senalp and AL-Duaiji , 2001), the lower part of theAfandi Formation of Syria (TV.Yankauskas and S.Talli,unpublished Syrian Petroleum Company report in Lababid and Hamdan , 1985, "Affendi"

In Konert et al,2001, "Affendi"in Brew et al,1999,2001)and the upper part of the Dubaydib Form The K2 member contains MFSO40 of late Ordovician late Caradoc ("Sandbyan") age (Sharland et al.,2001,2004;or MFIO40in the

Hasirah Formation in Oman ,Droste ,1997;Molyneux et al. 2006,,Aqrawi,1998a,b Konert et al,2001).

K4 member is Caradoc in age and most probably contains MFSO40 of late Ordovician late (Caradoc=Sandbian) age (Sharland et al., 2001, 2004) or MFIP40 in the Hasirah Formation in Oman (Droste,1997, Molyneux et al.,2006.

The K5 and K6 member is correlated to the Kahfah Member of the QasimFormation in Saudi Arabia (Vaslet et al.,1987;Senalp and AL-Duaiji,2001, the upper part of the Swab Formation of Syria(Y.Kauskas and S.Talli,unpublished Syrian Petroleum Company report in Lababidi and Hamdan ,1985;Konert et al.,2001,and the lower part of the Dubaydib Formation of Jordan; Aqrawi, 1998; Konert et al.,2001

The Khabour K5 and K6 members in Akkas-1 probably correlate to the Middle Ordovician (Liandeillo=Darriwillin) Kahfah Member of the Qasim Formation in Saudi Arabia (Vaslet et al,1987,1994).The Kahfah Member is divided in to lower and upper units, which are separated by a disconformity, and the two units may correlate to the Khabour K6 and K5 members. penetrated completely in (AKK-1) and not penetrated (Akk-2,3,4,5,6) Fig 2,3,4 . Table -1,2.

The K7 members is early Ordovician as suggested by Baban (1996) then MFIO30 would have to be positioned higher - up in the Khabour formation. On the basis of its shale lithology and great thickness ,the K7 member probably correlates to the Hanadir Shale Member of the Qasim formation in SaudiArabia ,Vaslet et al,1987, Senalp and AL-Duaiji ,2001, the black graptolite shales near the base of the Swab Formation in Syria (T.V. Yankauskas and S. Talli, unpublished Syrian Petroleum Company report in Lababidi and Hamdan,1985; Konert et al ,2001, Senalp and AL-Dyaiji,2001,and the shales near the middle of the Hiswah Formation of Jordan Andrews et al ,1991,Aqrawi,1998a,b Konert et al 2001.1991,Aqrawi,1998a,b.

The Khabour K7 member,on the basis its probable "Lianvirn" age (F.A1 - Juboury, in Al-Sammarai et al.1994), probably contains MFSO30 of Middle Ordovician " Lianvirn" age (Sharland

et al.,2001,2004, or MFIO30

positioned in the basal shales in the Saih Nihayda Formation in Oman (Droste,1997;Molyneux et al,2006). I f ,however, the age of According to R.Wetzel (in van Bellen et al.,1959), the exposed Khabour quartzites and shales are about 2,000m(6,560ft) thick in the Ser Ashuti Mountain Area of Turkey. The entire Khabour Formation is correlated to the Zardkuh Formation of southwest Iran (Zagros Mountains),and the Bedinan Formation of southeast Turkey, Konert et al.,2001.

Sandstone Petrography Description

Sandstone Mineralogy:

Khabour Members, shallow marine sandstones are classified as quartz arenite, subarkose and sublitharenites after Folk (1974),Fig-6,Table-2. Their detrial mineralogy is dominated by quartz (both mono-and polycrystalline 54-90%) with lesser chert (5-19%), feldspar (2-7%) lithic fragments (metamorphic and igneous,1-3%),mica (biotite),and other grains (including pyrite and heavy minerals dominated by zircon ,tourmaline and rutile (0.5-2%) Table – 2.

Mono-crystalline quartz is the most abundant framework grains. Quartz grains may be with or without inclusions, the most common inclusions recognized are vacuoles, acicular Rutile, spherulitic zircon, muscovite, apatite and iron oxides. Straight to slightly undulatory extinction is frequent type in the quartz studied. Plagioclase dominates over microcline and. Orthoclase. Much of plagioclase and orthoclase appear to be altered to clay minerals. Quartz Types, inclusions and undulosity indicate a derivation from a dominantly granitic source with subordinate input from the metamorphic rocks.

Using the extinction kinds of monocrystallin quartz and the polycrystallinity of quartz of the

Khabour Formation, it is deduced that the plutonic igneous and metamorphic rocks is the main source suggested for the Khabour sandstone. These rock types are common in the crystalline complexes of the basement rocks of Iraq(Buday,1980).

The Khbour sandstone generally are medium to fine grained, moderately well-sorted. Micaceous fine sandstone are commonin the K3,K5 of laminated sandstone,which intercalates with shale and represents an off-shore tidal-storm deposition.

Table 1 :Modal composition of Khabour sandstones

Core No.	Depth (m)	Detrital Composition						Cement of Total %		
		Q%	F%	R.F.%	Mi%	Mx%	Oth%	Si	Co_2	Fe+Cl
C/11	2337-38	82	8	4.5	1	2.5	2	1.4	12.5	0.3
C-11	2339.5	91	3	2	1	2	1	1.2	5.1	0.1
C-11	2341.50	85	6.5	2	0.8	4.5	1.2	11.6	12.9	0
C-11	2343.50	85	6	4.2	2	2.5	0.7	2	1.5	0
C-11	2345.50	82.5	7.4	5.1	1.3	2.6	1.1	2	3	0
C-12	2360-61	84	4	2	3	5	2	2.1	6.3	7.3
C-12	2362.-63	76	2.5	4.5	9.6	6	1.4	2	5	8
C-12	2368-69	92	2.5	2	1	1.5	1	3	4	5
13	2371-72	83	5	5.7	2	2	2	0.7	4.5	0.1
13	2372.-73	90	3	3.5	1	1	1.5	10	2	0
14	2385-.86	83	4	3.9	4	3	2	2.2	0.9	0
14	2387-88	81	5	5	7	1	1	5.6	1.6	2.1
15	2389-90	87	2	2	3	5	1	1.7	1.5	0
15	2392	90	2	2	3	3	0.5	1.6	1.2	0
16	2493	88	2	2.5	2	5	0.5	0.5	1.8	0
16	2494	85	4	3	3	4	1	1.0	6.1	0
17	2633	86	5	3	2	3	1	5	2.1	0
17	2637-38	82	4	6	3	3	2	4	3	0
18	3105	83.3	4.7	5.1	3.8	2.2	0.9	1.2	5	0.5
18	3108	87	2	3	2	1.5	4.5	1.1	4.2	1
18	3114	86	3	4	1	2	4	2.2	6.1	1.5
18	3115	90	2	1	1.5	3	2.5	3.2	5.3	0.4
18	3117	82	4	4	3	4	3	3	4	-
19	3172	83.8	4.3	4.8	0.8	6	0.5	2	5	0.5
19	3175	86.5	4.2	2.5	0.7	6.0	0.2	3	6	-
19	3177	89	3.1	1.9	1	3	2	2	5.1	-
19	3183	88	3	2	2	4	1	1.5	8.1	-
20	3552-53	85.6	3.3	4.1	2.8	3.3	0.9	3.8	1.4	0
20	3554	86	2	3	1.9	3.5	3.6	3.5	2.5	0

Q: Quartz, F: Feldspar, R.F.: Rock Fragment, Mi :Mica; Mx: Matrix, Oth: Others

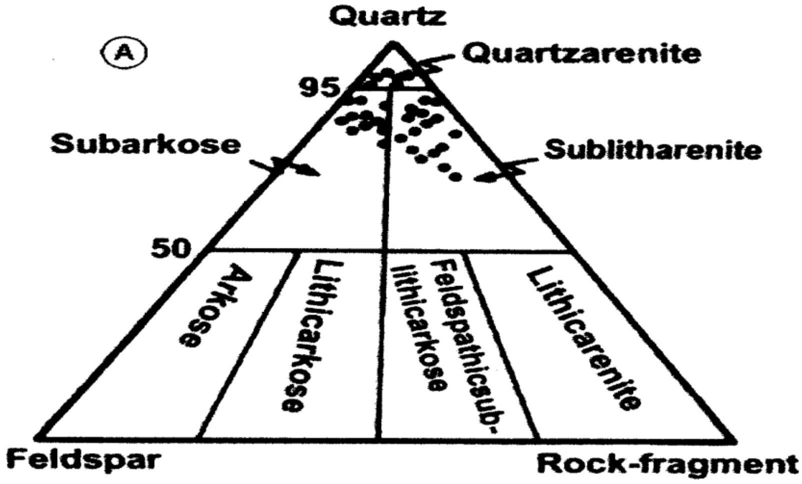

Fig.(5) khabour Sandstone Member classification.folk(1968)

Shale Mineralogy

Shale members that interbedded that with sandstone form about 60% of Khabour formation.Al-Quwaizy,(1997)and Al-hadidy,A.2001, study shale rocks interbedded wit sandstone of Khabour Formation by X-ray diffraction analysis and infrared techniques revealed that the Khabour shales are composed of illite, chlorite, kaolinite and mixed layers of illite-smectite clay minerals as well as quartz, feldspars and mica.

Diagenesis Model In Khabour Sandstone Members

Porosity enhancement and preservation are not the result of a single digenetic event but of series of digenetic events in Khabour Fm.Daigensis in these sandstone commonlay resulalted in the destruction of much of the original intergranulaer porosity and left dissolveld grains, clay-filled pores, and sheet like, pore throats typically very small .

That overlapped in time which include compaction, cementation, Dissolution and replacement of detrital silicates and alteration of micas, Fig-6. The digenetic history of sandstone reflect processes and variation in thermal history which observed as below .

1- Compaction

In the Khabour sandstones, a strong impact of compaction on sandstone diagenesis and porosity reduction was encountered. One common feature which shows the effect of compaction in the studied sandstones member, Fig .(6) .

Those of sublitharenite (micaceous sandstone) that were buried to depth part of Khabour Formation from 2400-3200m is the deformation and bending of mica between harder grains. The process will then lead to compression and distortion along the cleavage planes in areas of high compaction effects. In these areas alteration of mica(especially biotite)in to illite and /or chlorite Promoted other indications of compaction in the studied sandstones are the deformation and fracturing of quartz grains. The shape of contacts between the grains are considered to reflect the degree of compaction Wolf&Chilingarian,1976).

In the studied sandstones, sutured and concavo - convex are the most common in the deeply buried sandstones which means high compaction effect and higher pressure solution on the quartz grains. Pressure-solution may influence an increasing of fluid inclusion in the detrital quartz grains Dapples,E. C. 1971, due to the increasing of temperature and pressure. In the studied quartz, it seems that highly compacted and fractured grains are clouded by fluid inclusions.

2- **Cementation Authigenic Minerals**

Understanding the origine, abundance, spatial and temporal especially related to hydrocarbon accumulation in sandstone members of khabour formation. as well as distribution of proe - filling cement remain acritical unsolved problem in reservoir quality. The following minerals in a decreasing order of their volumetric importance form the common cementing materials in the Khabour sandstones members.

Carbonate(Calcite and Dolomite)

Calcite and dolomite cement are the main types of cement in the studied sandstone. The dolomatite is mainly of ankerite,Fe - dolomite. The cement occurs as patchy or poikilotopic pervasive and healing of fractures. According to the physical classification of carbonate cement in sandstone set by Dapples,E.C. (1971).

The crystallization of carbonate cement in Khabour sandstone shows either local expansion of intergranular spaces and rearrangement in the packing of detrial grains or recrystallization without modification in the arrangement and hence incorporated clay minerals precipitated.

The calcite cement replaces also the feldspars partially or completely, the replacement affects both potassium feldspars and plagioclases. It is generally random and may start by corrosion of grain boundary and continue through the cleavage and fractures. It seems that the presence of illite coats around detrital feldspar grains is found to hinder the replacement by calcite.

Blatt et al. 1980 and Mc Bride,1988 , discussed several possibilities concerning the origin of carbonate cementin sandstones however, a late secondary origin appears very likely to be due to the evidence of its corrosive and replacive effects on the Khabour detrital grains and overgrowths. Moreover it appears that aminute proportion of calcite cement was produced, by the co2 from shale interculation in Khbour (Ordovician)sediments. Most of calcite is produced and derived locally from dissolution of plogclase within the reservoir. The deeply buried Khbour sandstones and hence increasing temperature and pressure as well as presence of saturated carbonate pore water favour precipitation of calcite cement.

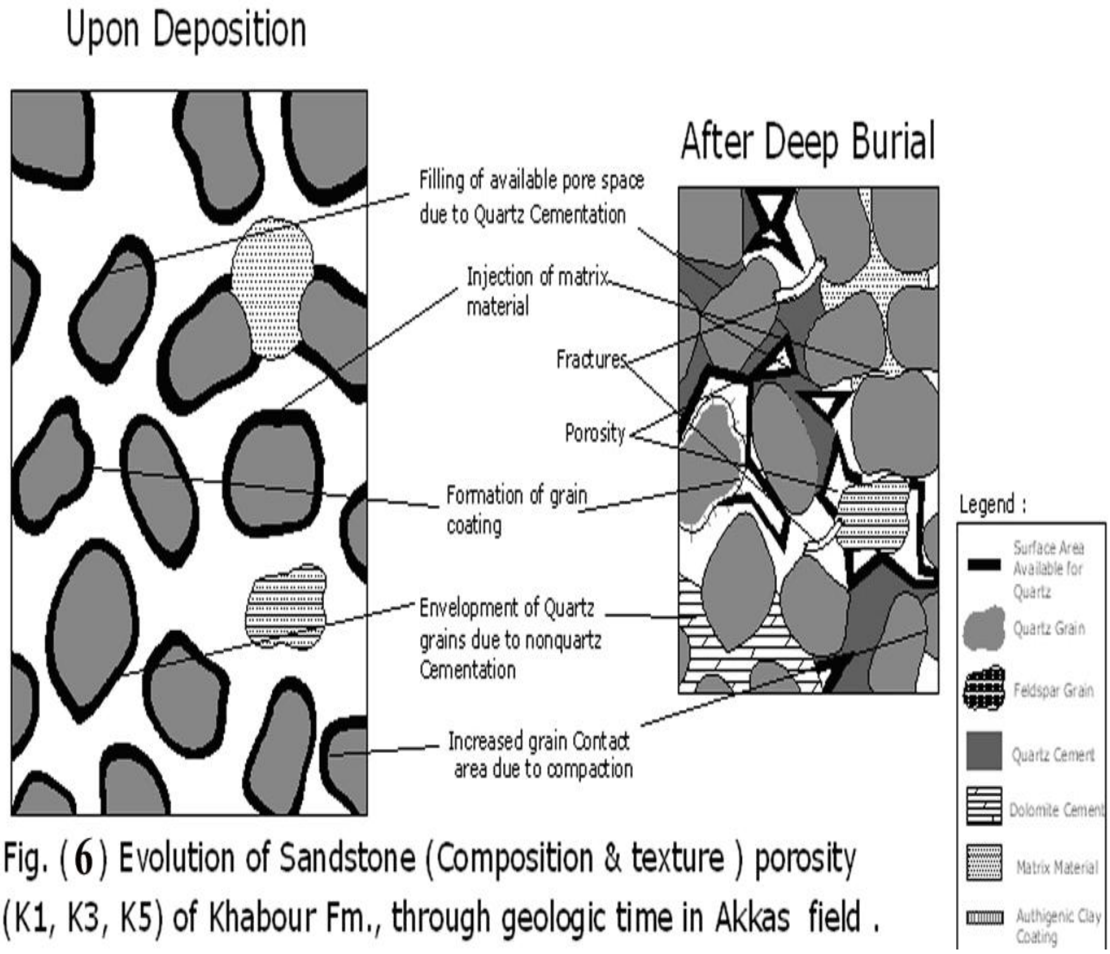

Fig. (6) Evolution of Sandstone (Composition & texture) porosity (K1, K3, K5) of Khabour Fm., through geologic time in Akkas field .

Quartz Cement

This equates to a minimum temperature for quartz cement of about 125-140c, (Worden, retal,2000). Silica in the form of quartz ,is another abundant cementing material in the studied sandstone Table .(3).

The quartz overgrowth are clearly recognizable in the grains which possess a thin faint line of demarcation (iron oxides and clay minerals) marking the original grain boundary Fig.(6,A).Quartz overgrowth locally shows triple junction grain contacts Fig.(5,F).They are texture selective, and mostly common in coarser grained sandstones that are well sorted and free of clay matrix because the presence of clay around detrial quartz grain inhibits overgrowth. Silica that formed the cement in the Khbour sandstones may have been formed inside the sand beds because there is significant pressure solution of silicate grains in the sandstone studied. The quartz cement increase with increasing burial depth. Feldspar dissolution and partial or complete replacement of detrital. Silicates (quartz or feldspar) by calcite can release sufficient amounts of silica needed for the quartz cement(McBride 1988).But compaction affects on interbedded shales and hence.Silica releasing by the transformation of smectite to illite (the present study) from an outside Source for the silica introduction to the sandstones depth and ductile content of the sandstone together appear to control the amount of quartz content.

Chlorite And Kaolinite (Clay Cement)

Authignic clay occurs in few amounts (Table2)as replacement of detrial feldspars. It sometime forms patches within the calcite cement or separate patches of kaolinite or as acoats of illite and / or chlorite rimming the detrital grains . Chamosite Fe - rich chlorite is also seen as adark green patches.

3- Replacement And Alteration

Replacement includes of dissolution detrital silicate grains(quartz and Feldspars) by carbonate as mentioned earlier and redeposition of the dissolving materials to form new authigenic minerals. Dolomitization can be regarded as replacement process by which the Mg-saturated solutions affect in the replacement of calcite cement by Fe dolomite (ankerite).The Fe-needed to form ankerite may be introduced either from smectite into illite transformation(Boles&Franks,1979) ,or from the dissolution of biotite. both recorded from the present study.

Alteration is another diagentic process affecting the studied sandstones.It is clearly observed by the alteration of feldspars and mica. both types of alteration are facilitated by the burial diagenesis.

Altered feldspars graivs(both plagioclase and potassium feldspars)are observed as cloudy with clear clay minerals along the cleavage planes or rimed altered grains. Dissolution and alteration of feldspars show significant increase in the microfractures and hence an increase of secondary porosity of the sandstone.

Alteration of mica happens along the cleavage planes of muscovite and biotite in the areas of high compaction effects.This feature is observed by alteration of biotite in to illite and / or chlorite and iron oxides. oradM (1990)refers that alteration of mica occurs at depths more than 3000m,and several authigenic minerals by products of mica alteration Include Fe-dolomite, quartz overgrowth, abitization of K-feldspars and Ti-oxides will be observed.

Reservoir Sandstone Predictability

To improve porosity and pearmeability prediction to the level of accuracy of geoloigical control (texture, tectonic, fault style)and thermal maturity. The reservoir quality decreasing with increasing thermal maturity reflecting temperature control on sandstone matrix porosity is diageniticaly reduced with depth as the best reservoir is bed2 middle K1 ,as well as K1 member become good properties to direction North West of Akkas field as AKK-I,3,5 Wells as sand rich and intensity of fracture.The reduced of cementation related to migration replace water by hydrocarbon is less slow cementation so the intergranular porosity of sandstone may be preserved. as well as presence of pervasive chlorite rims that inhibited quartz overgrowth, that leave pore throat relatively open.

Secondry Poroisity

Petrophyics is acritical technology required for understanding ,pore geometry, secondary porosity and fracture intensity ,all under overburden stress to predict reservoir performance Secondary porosity had formed by partial to complete dissolution of feldspar and other unstable grains and makes only modest contribution to total porosity. As well as calcite dissolution and micro fracture in brittle quartzite inK1,K3–sand rich ,which increase to wards wells AKK-3,2 and to fault plane North West. porosity preserved due to the

presence of pervasive chlorite rim that inhabitant quartz overgrowth cement.

Sandstone porosity in K1,K3 is about (7-10)% core No.1 and varying with the increasing of burial depth. This sandstone member are deformed by brittle processes that produce fracture zone

.Here it should be noted that permeability of fracture increases with increasing fluid pressure (Walsh 1981) The Khabour G.W.C was not observed in any well.

The secondary porosity could have been preserved by pore pressure buildup by migrating gases and light oil generated (Lubomir F. et al. 1990) .

Hydrocarbon System :

Maturation studies (AL-Haba et al.,1991,1994).the shale member ,Kabour Formation are highly –mature, marine, organic-rich with total organic carbon contient (TOC)VALUES OF0.9-5% by weight.

The net source rock " hot shale" Akkas Formation (Silurain)can reach a thickness of up to70m.in Akkas wells and TOC OF 1.0-16.6% in Akkas-1.which are currently in the oil- generation zone .Aqrawi ,1998,Fig-7 showed aburail history model of the Akkas-1 well in which the silurain hot shale entered the oilzone in late Paleozoic and remains their, today, act as

main source rock to sandstone members of younger age Ordovician).

Based on seismic data Al-Haba et al.(1994) concluded that fault along the estern flank of Akkas field, provided path way for hydrocarbon migration from the lower silurain source rocks to the K1,K3,K5 sandstone members (Khabour Fm.) Ordovician younger.

Migration history to have been complex and to have involute both local and long distance movement, fault and fracturing prometed vertical migration and lateral updip modle.

So the scenario must need 3D seismic survey have been performed to accurate identified of trape style. These faults compartmentalize reservoir, which communication between fault blocks and different juxtaposition of sandstone and shale members of khabour fm. across faults surface the fault block ,petroleum maturatiy

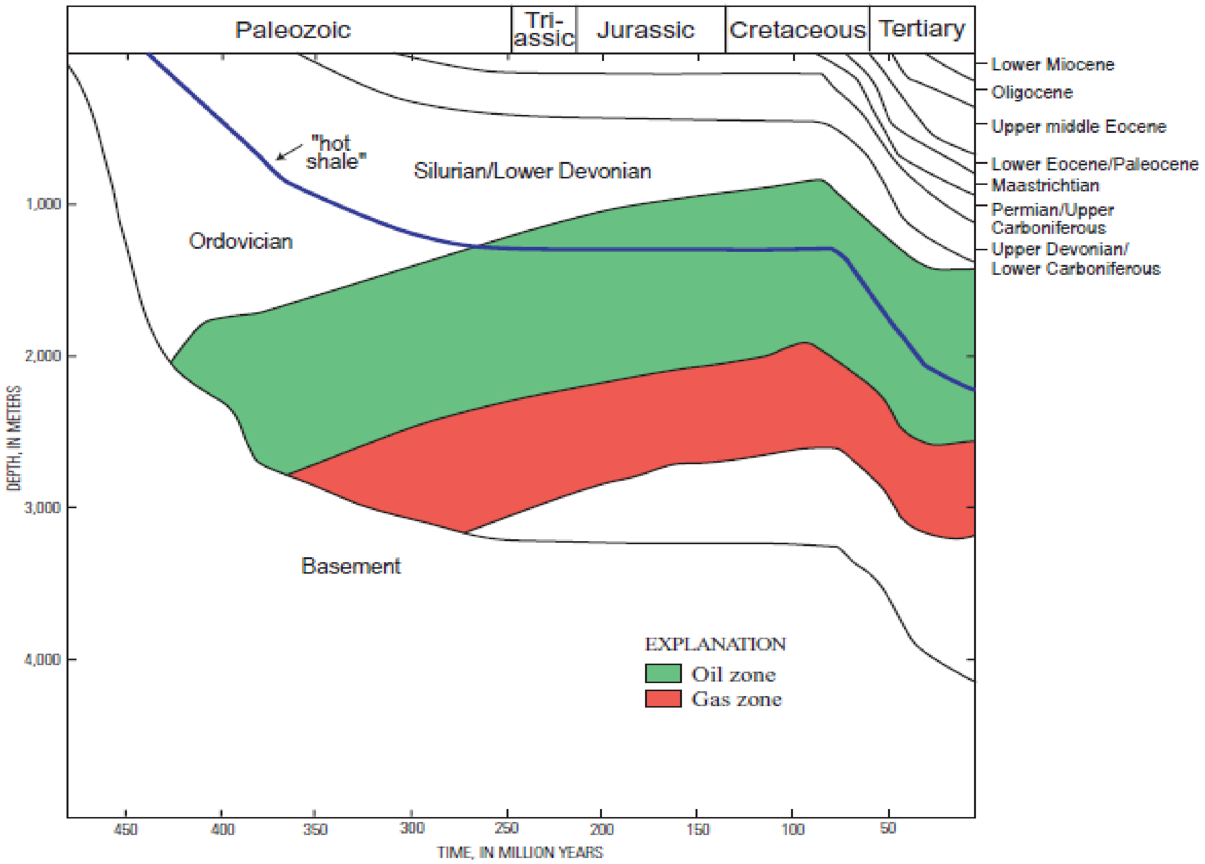

Fig.(7) Burail history Model of AKK-1,Aqrawi,A.1998

Condensate Blockage Phenomenon

Condensate blockage is the build-up of liquid around the well bore,When BHFP (bore hole flowing pressure) fall below dewpoint pressure reducing the effective gas permeability and very important for lowering well deliverability.

The accumulation of a liquid condensate in the near well bore region. and when the well is on decline (tubing-pressure limited).The near well condensate blockage control well deliverability.

Condensate Blockage Depend On Factors

a. Fluid propties, it consist of Methane, and other short chain hydrocarbon.
b. Gas analysis.
c. Reservoirs members characteristic.(Tight sandstone).
d. Flow rate and pressure.

Factors Confirm To Condensate Blockage

a – An increase in GOR .

b – Decline in flow .

Improve Production Rate

Several methods have been proposed to restore gas production rates after a declinedue to condensate and / or water blocking Gas cycling has been used to maintain reservoir pressure above the dewpoin .

1 - Hydraulic Fracturing

Hydraulic fracturing is the most common mitigating technology in siliciclastic reservoir. hydraulic fracturing has been used to enhance gas productivity . but is not always feasible or cost – effective . Hydraulic fracturing is commonly used technique to restore the gas productivity of wells in which the flowing bottom hole pressure has dropped below the dewpoin.

2 – **Horizontal Wells**

Reservoir members of Khabour Formation " low permeability -Micro fracture dependent " is related to horizontal drilling , The best trend is "K1 Upper Sandstone ember .

3 – Large tubing.

4- Chemical Treatement.

Conclution And Discussion:

1- Khabour formation subdivided into eight members (K1 –K7) as multiple Reservoirs overlying by intra shale bed to form effective top seals.

2- K1,K3 sandstone members the best targets of drilling in Akkas field.

3- K1 Member" upper sandstone, K1 Member can be divided in to three beds according to sandstone maturity (shale – sand rich), Middle zone is best reservoir, which thermal maturity.

4- The main diagnitic model has affected the buried Khabour sandstone members, that have modified reservoir quality first is thermal burial depth greater 2000m. An. early events,compaction, formation of clay chloriteand illite coat and cementation (Quartz and calcite)as reducing reservoir quality.,They were followed calcite dissolution, feldspar leahing and fracturing brittle sandstone as secondary porosity the reduced of cementation related to migration replace water by hydrocarbon is less slow cementation so the porosity of sandstone may be preserved.

5- Reservoir quality enhanced by Secondary porosity (fracture quartzite sandstone)could preserved by pore pressure at depth 2300 m. build up from short or long migrating gases from source intrashale member or from hot shale.

6- Migration factor is important in this scenario, such as wrong timing of migration and structural development or lack migration pathway although theirs a good sandstone reservoir . Migration updip from shale (source beds) which is younger source (Silurian – Hot shale) to older carrier and reservoir sandstone Khabour (Ordovician). rampant by graben –horst structure as Akkas.

7-The near well condensate blockage control well deliverability.hydrolic fracturing, Horizontal can used to enhance Gas productivity and deliverability.

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