

Geologic, Seismic, Climatic, and Oil Production Controls on Hydrocarbon Seepage, Al-Ahmadi, Southeast Kuwait*

Muhammad W. Ibrahim¹

Search and Discovery Article #20474 (2020)**

Posted February 24, 2020

*Adapted from oral presentation given at 2019 AAPG Hedberg Conference, Hydrocarbon Microseepage: Recent Advances, New Application, and Remaining Challenges, Houston, Texas, June 18-20, 2019

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¹Target Exploration Consultants, London, United Kingdom (m.ibrahim@targetexploration.com)

Abstract

A series of explosions destroyed several houses at Al-Ahmadi Town in southeast Kuwait during 2010 and 2011; they were initially attributed to gas leakages from discarded old domestic gas supply system. The incidents led Kuwait Oil Company (KOC) to commission a surface geochemical survey of one of KOC's Al-Ahmadi housing blocks which was affected by the explosions. A serious gas explosion in Al-Ahmadi on the 18th of May 2015 prompted an evacuation of a number of houses in Al-Ahmadi, followed by a prolonged investigation of the source(s) of the recurrent gas leakages. This article is a review of the published surface geology, subsurface stratigraphy, seismic structural motives and consequences of prolonged production operations of Greater Burgan Oil Field - with special focus on the surface and subsurface stratigraphy and structure of the Al-Ahmadi Ridge of Greater Burgan Oil Field, which is situated beneath the afflicted Al-Ahmadi Town - in search of natural seepage(s) rather than man-made leakage(s) of the exploding gas.

The review revealed that the gas explosions were not likely caused by trapped gas in the discarded domestic gas supply network, and argue for an imperfect Greater Burgan oil trap, with inherent ancient oil and gas seepages propagated by environmental side effects of prolonged oil production operations, which attained recurrent cycles in response to climatic seasons, and probably amplified by the occasional regional earthquakes.

The review concludes that under current environments and production practices, the historic trend projects an increase in the volume and number of gas seepage sites over and beyond the footprint of Greater Burgan Oil Field. Furthermore, the review recommends some gas seepage mitigation habitat measures and the deployment of mobile technologies for regular surveying and monitoring of methane and H₂S build-up in the air, and in the shallow subsurface reservoirs below the Ahmadi Town as routine risk management procedures.

Selected References

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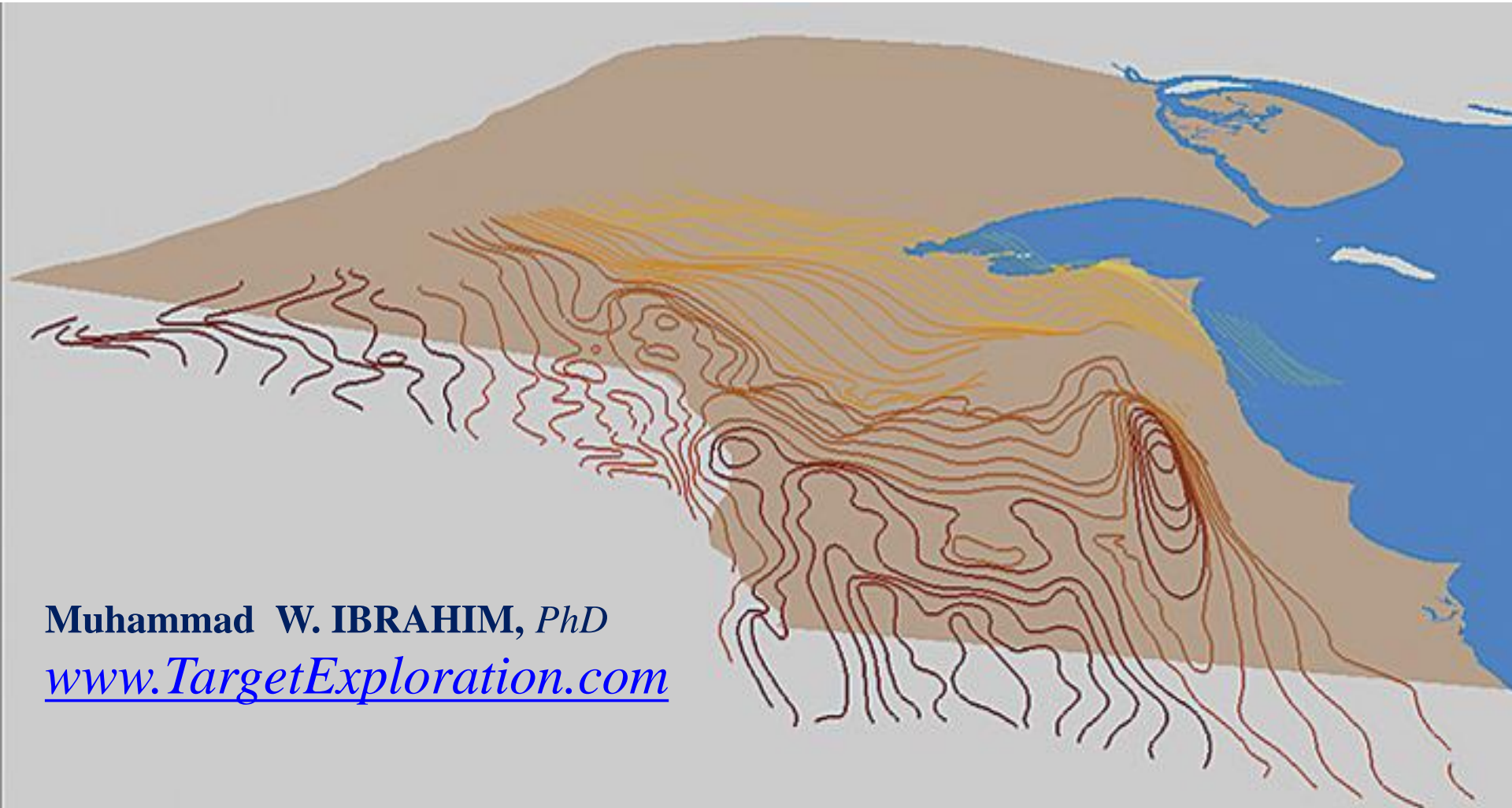
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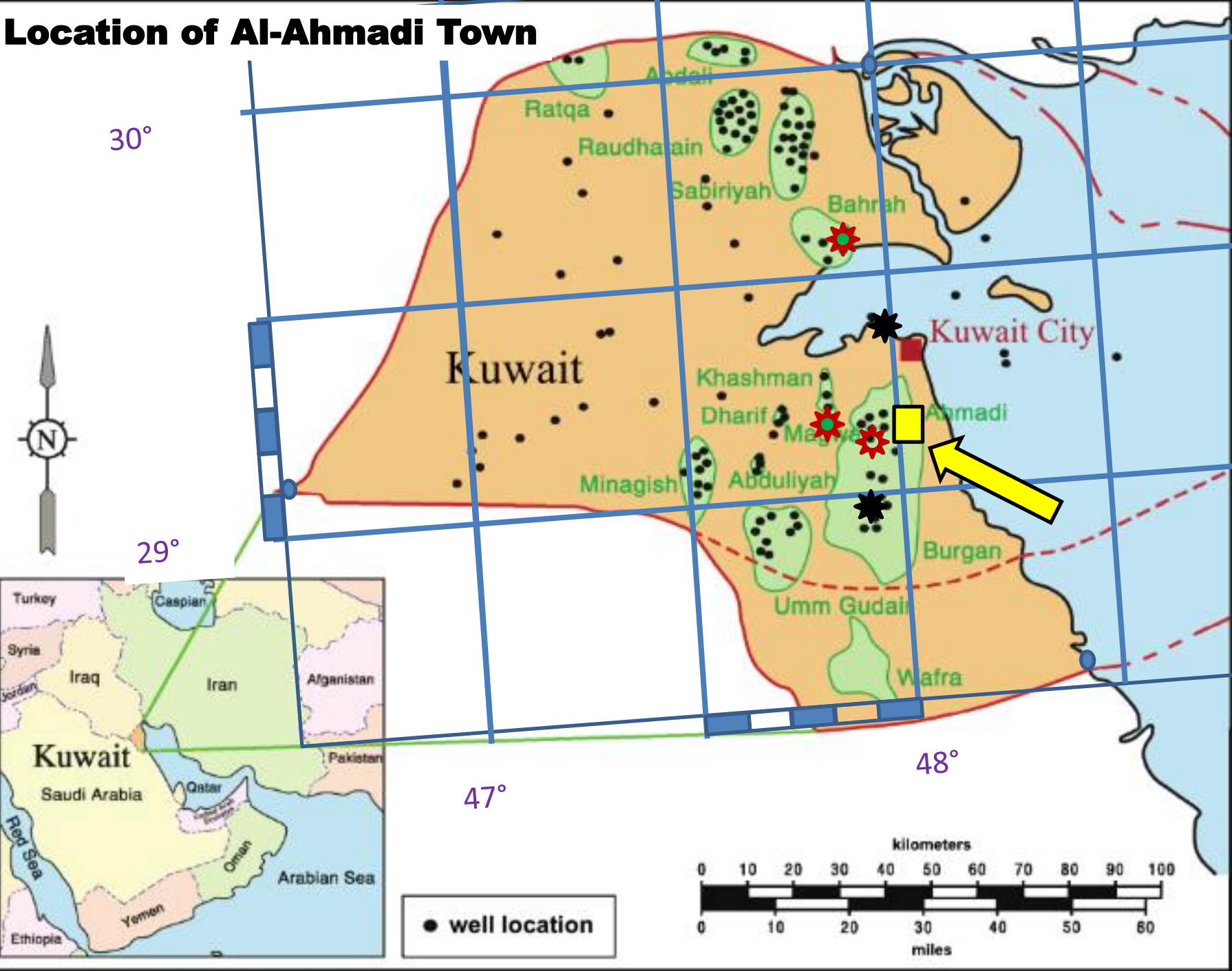
Muhammad W. IBRAHIM, *PhD*
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Geologic, Seismic, Climatic and Oil Production Controls on Hydrocarbon Seepages at Al-Ahmadi Town, SE Kuwait



- 1. Gas seepages and Gas incidents at Ahmadi, SE Kuwait**
- 2. Post-2010 Gas seepage incidents studies of Ahmadi**
- 3. Definition, worldwide and HC seepages of Kuwait**
- 4. Stratigraphically induced Gas seepages at Ahmadi**
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- 6. Impact of climatic cycles on Gas seepages**
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Location of Al-Ahmadi Town



Gas Explosions in Residential Ahmadi in 2010

Date : 19/10/2010

By Mubarak Al-Hajri KUWAIT, Oct 19 (KUNA) -- The gas leakage in al-Ahmadi area is contained and there is no reason to be worried, Kuwait Fire Service Directorate (KFSD) said Tuesday. After a comprehensive meeting with a team of Kuwait Petroleum Corporation (KPC), along with international experts, KFSD said it ran a scan on residential "areas of al-Ahmadi and reports came "comforting. All procedures in this regard were taken, including the complete cutting out of the gas network in the area two months ago in order to secure residents' safety," KFSD Deputy Director General Brigadier Youssef Al-Ansari told KUNA. The odor currently existing in the area is a result of previous, but limited leakages," Al-Ansari noted, adding that both KFSD and KPC are constantly - on a daily" basis - monitoring the situation. (end) mah.hb KUNA 191657 Oct 10NNNN



28 JAN 2010

3 FEB 2010

Circa ?19 Oct 2010

11 NOV 2010

Circa ?19 Dec 2010

Summary: Kuwait, Muharram 13, 1432 / Dec. 19, 2010, SPA -- Undersecretary of Kuwait Ministry of Interior Lt. Gen. Ahmad Abdullatif Al-Rujaib said Sunday the ministry pursues a thorough probe into the gas leakage accident which took place in Al-Ahmadi city earlier this month. "The results of...



EXTENT OF ONE OF THE EXPLOSIONS

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Detection of Natural gas leakage in Al-Ahmadi area, South of Kuwait: A preliminary study

Ahmed Al-Rashed

Department of Science, College of Basic Education, PAAET, Kuwait.

ahmedbufarsan@yahoo.com

Abstract: The Block No.1 of Al-Ahmadi Town suffers from repeated cycles of natural gas leakage in the last decade. Each cycle has its own characteristics regarding the leaking period and gas intensity. Some inhabitants of this Block moved out of their houses due to their fear about the spread of diseases such as asthma and possible disaster such as fires due to gas emission. The earlier investigations has not yet reached the reasons behind the gas leakage, but limited the reason to one of the following: geological factors; the 50 year old gas network; and the new gas network. Intensive geochemical survey represented by 47626 gas readings has been conducted inside and around the Block No. 1 of Al-Ahmadi Town. This is to shed light on the possible reasons behind the repeated natural gas leakage phenomena. This is to locate and identify the leakage source, which will be helpful for planning to solve the gas leakage problem and to prevent any possible further gas leakage from the subsurface and also to prevent any possible untoward incident due to gas leakage. The survey has been run using an up-to-date Soil Gas Detector (Crowcon Gas-Detector) that based technically of the Flame Ionization Detection (FID) technique and utilizing a stream-mode surveying technique. Inspection of the iso-methane contour map of the surveyed area revealed that the study area is characterized by low to medium gas leakage intensity (0-500 CPS). Extremely high local anomalies are recorded to the west of the study area, which attains gas intensity up to 4000 (CPS). However, probable source of gas leakage may exist NE ward of the study area as an increase in the gas intensity up to 1000 CPS is remarkable at this direction. The probable reasons of the gas leakage is may either due to near surface artificial or natural gas leakage sources. The differentiation between these possible sources requires detailed background on the sub surface infrastructures, such as pipeline network, as well as the near-surface joints or fractures (neotectonics) of the study area. Further shallow geophysical surveys are recommended for mapping the near surface weakness zones, microstructures and neotectonics.

[Al-Rashed, A. **Detection of Natural gas leakage in Al-Ahmadi area, South of Kuwait: A preliminary study.** *Nat Sci* 2014;12(3):87-93]. (ISSN: 1545-0740). <http://www.sciencepub.net/nature>. 12

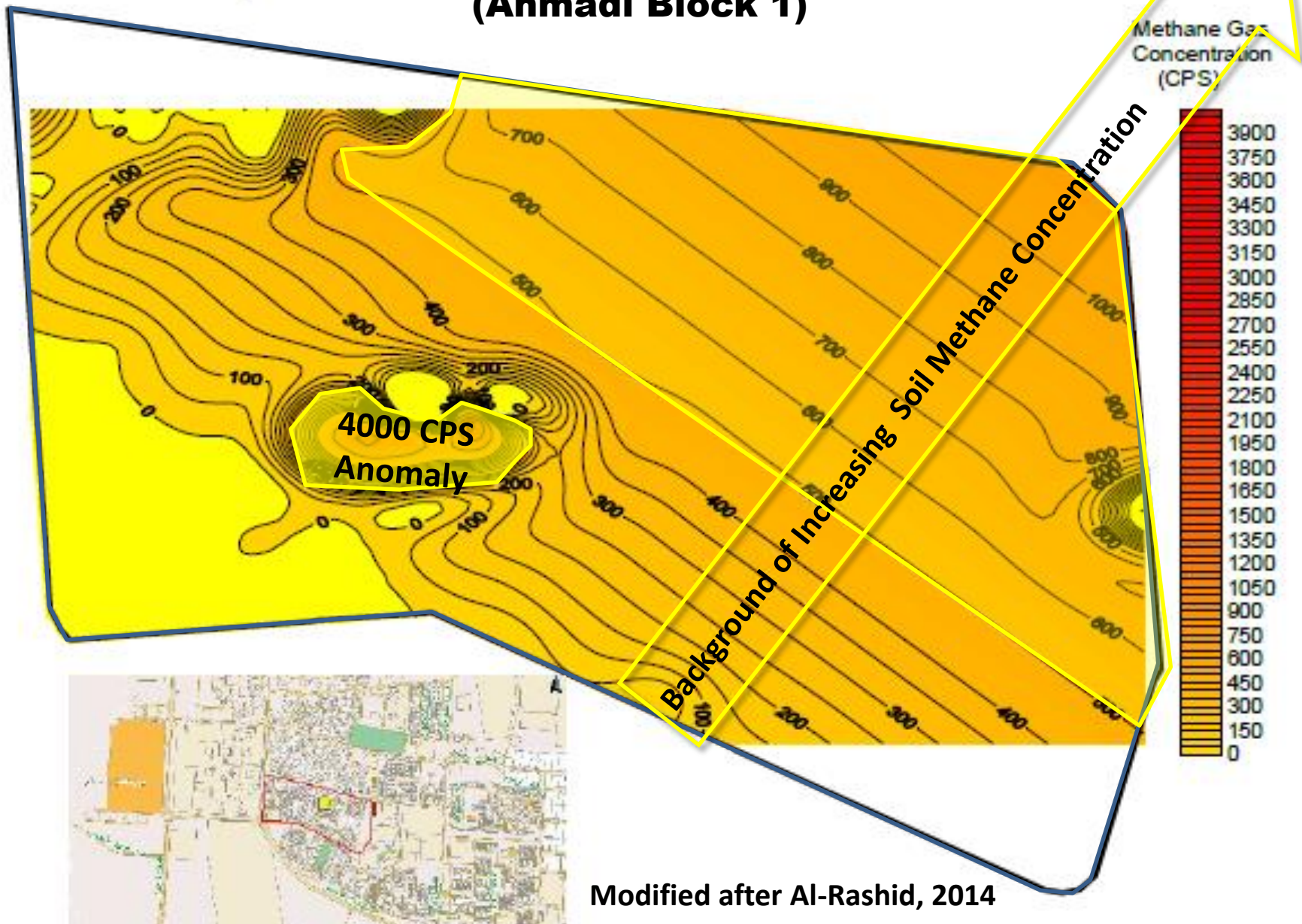


Locations of 47262 Gas Readings Traverses in Ahmadi Block 1



After Al-Rashid, 2014

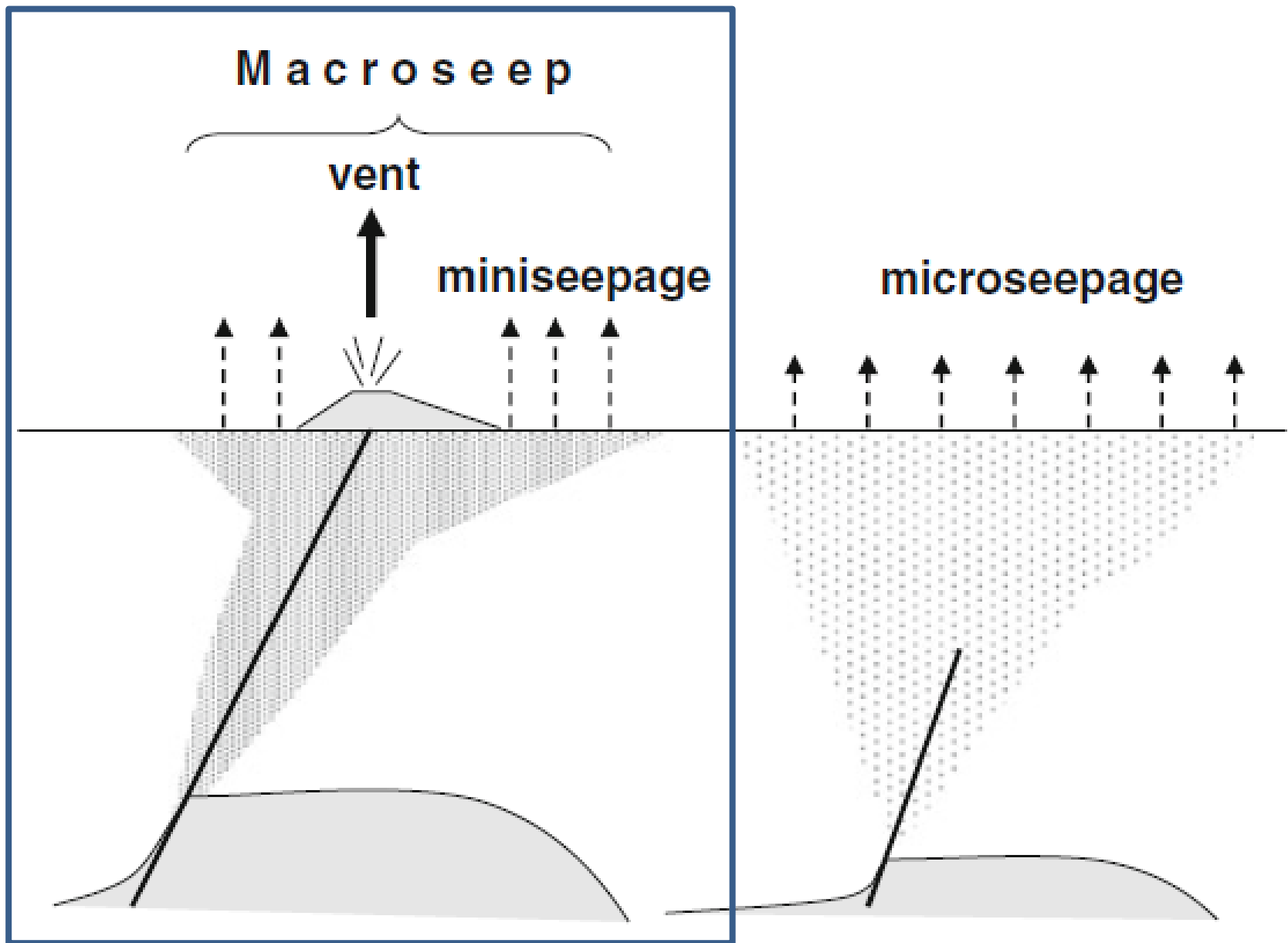
Micro-seepage Soil Methane Gas Concentration Contours (Ahmadi Block 1)



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Reservoirs

After G. Etiope, 2015

Documented on-shore macro-seepages of Kuwait

30°

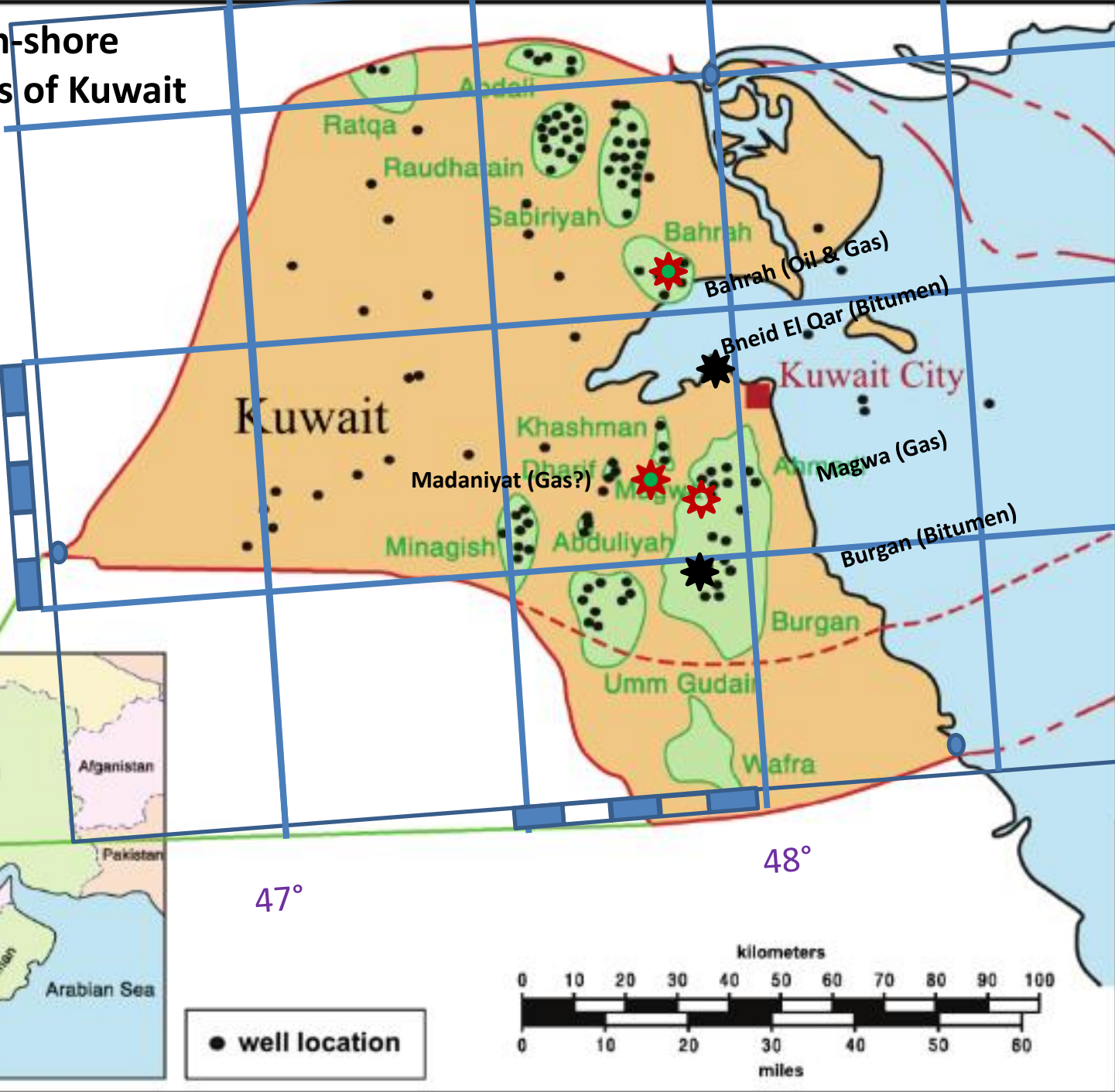
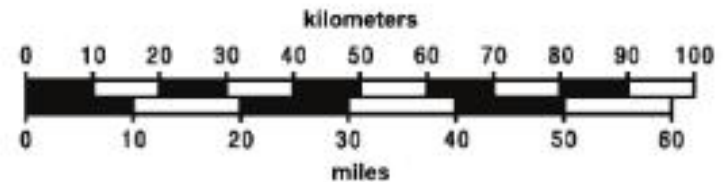
29°

47°

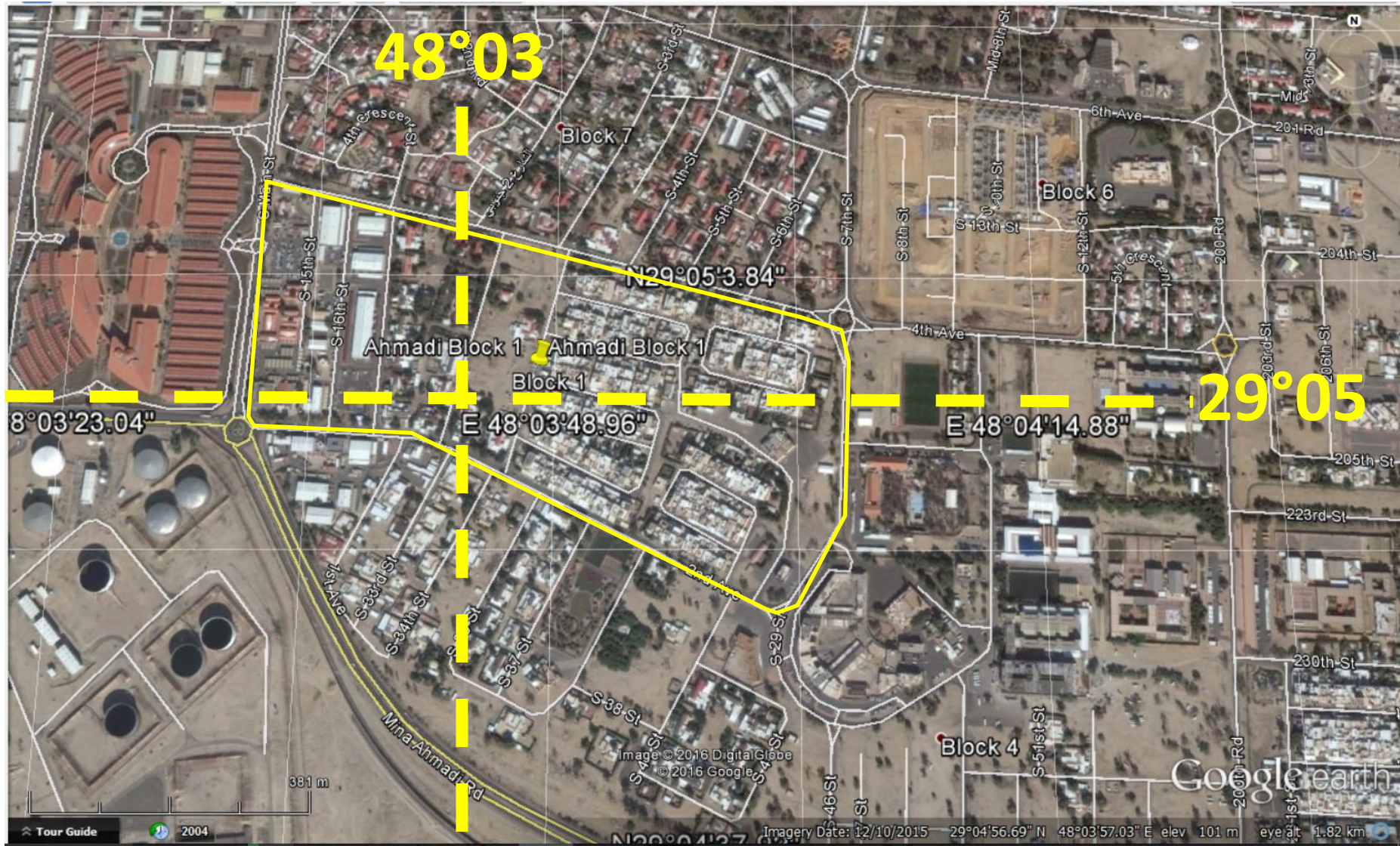
48°



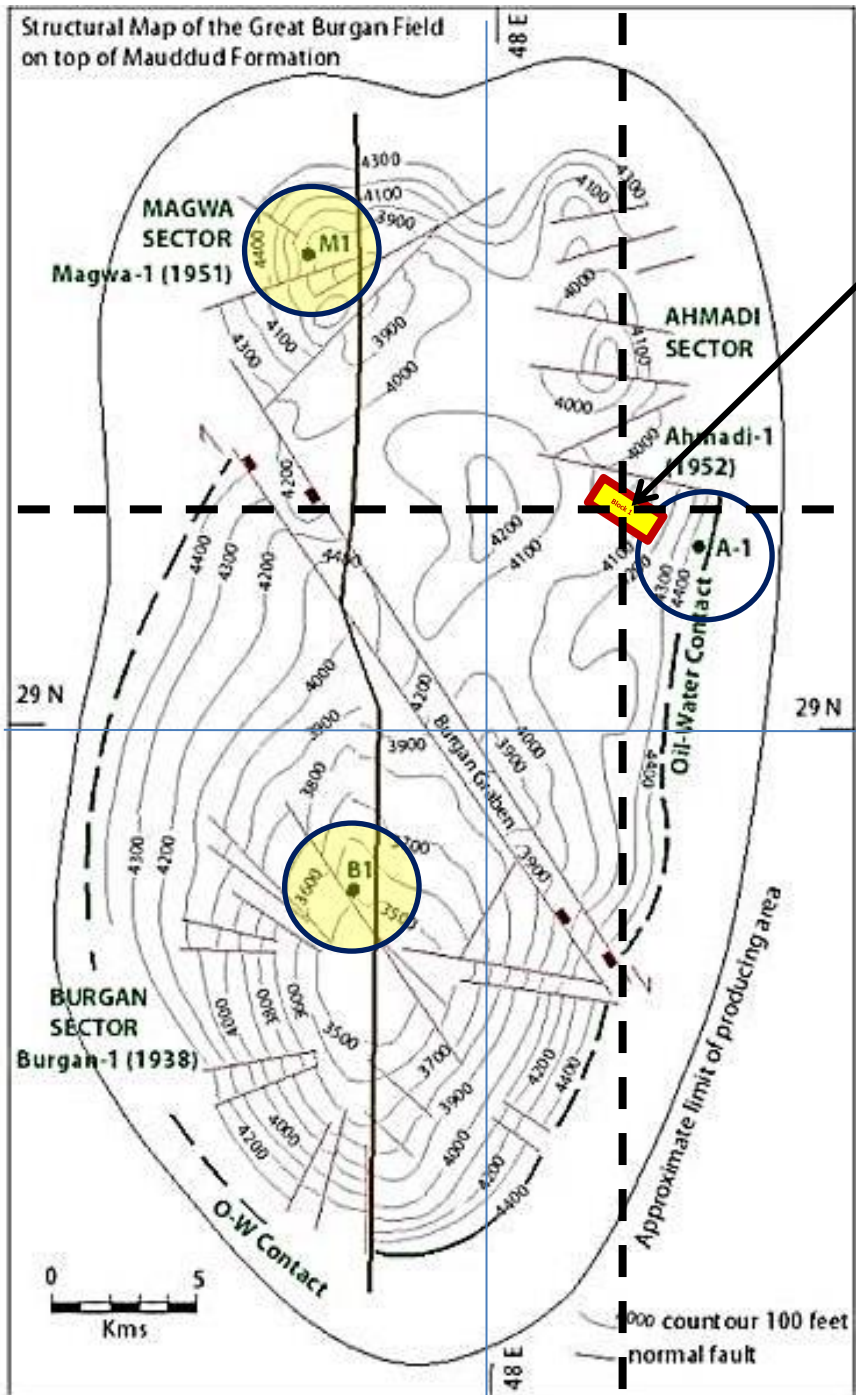
● well location



Coordinates of >4,000 CPS Soil Methane Concentration Anomaly in Block 1, Al-Ahmadi

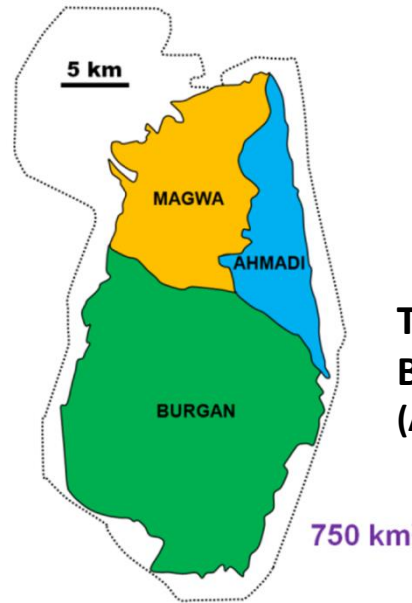


Structural Map of the Great Burgan Field
on top of Mauddud Formation



Structural Contours of top of Mauddud reservoir of Greater Burgan Supergiant Oil Field (Brennan, 1999)

Ahmadi Block 1



The 3 Sectors of Greater
Burgan Supergiant Oil Field
(Alkhaledi et al 2015)

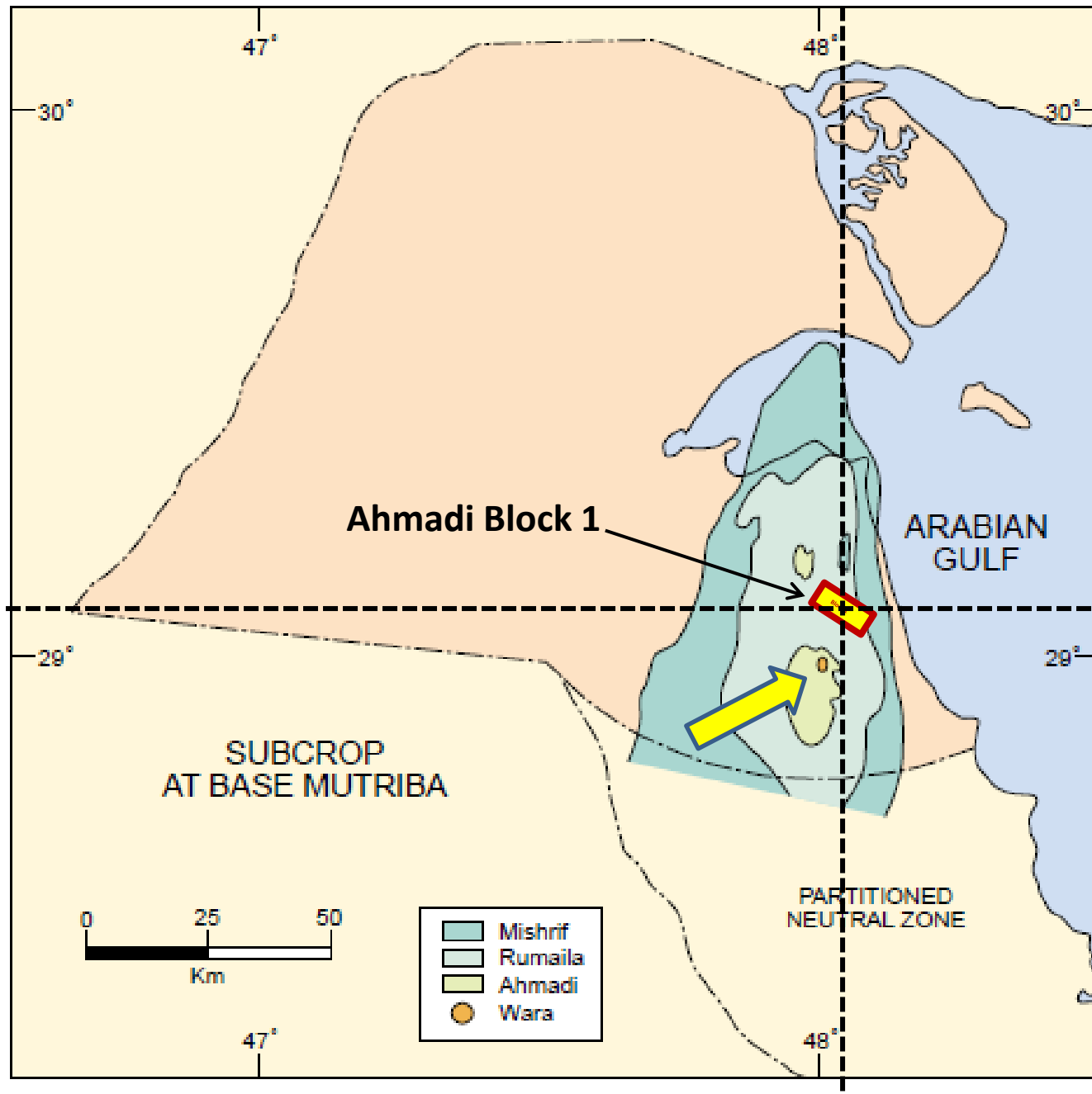
- The 1951 Discovery Well Magwa-1 (M-1) was drilled near a Gas Macro-seepage.
- No HC Seepage was detected near the 1952 Discovery Well Ahmadi-1 (A-1) that drilled an Ahmadi Ridge Topographic High.
- Discovery Well Burgan-1 (B-1), was drilled in 1938 near a Bitumen Macro-seepage.

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PERIOD / EPOCH / AGE		Ma	GP	FORMATION	THICKNESS (m)	RES	Stratigraphic Section of Gt. Burgan	
CENOZOIC	PLEISTOCENE							
	TERTIARY	PLIOCENE		KUWAITI	Dibdibba			Final Tethys Closure Zagros Collision
		MIOCENE	23.3		Lower Fars	45-365		Development of Zagros fold/thrust belt and Zagros foredeep
					Ghar			Closure of Tethyan ocean onset of
		OLIGOCENE	42.1	HASA	Gammamir	180-240		Rus Formation Anhydrite Mbr is sealing Umm Er Radhuma HO Reservoirs
		EOCENE	47.2		Rus	100-140		
	PALEOCENE	53.3	Umm Er Radhuma		450-550		from northwest to southeast	
		60.5					Deformation of foredeep	
	CRETACEOUS	MAASTRICHTIAN	67.8	ARUNA	Tayarat	200-350		
			72.7		Qurna	18-90		
77.8			Hartha		0-275			
85.5			Sadi		10-350			
86.6			Mutnba Khasib		30-260			
CONIACIAN		89.7	WASIA	Mishrif	0-80		Ophiolite obduction onto Arabian Margin	
		91.9		Rumaila	0-150			
CENOMANIAN		93.6		Ahmadi	50-130		Ahmadi Shale Mbr is sealing, Wara, Mauddud and Burgan Light Oil Reservoirs	
		95.3		Wara	0-70			
		97		Mauddud	0-130			
ALBIAN		104.5		Burgan	275-380		Minor tectonic shortening on south Tethyan Margin	
		112						Break-up at north Tethyan Margin



(After Carman 1997)

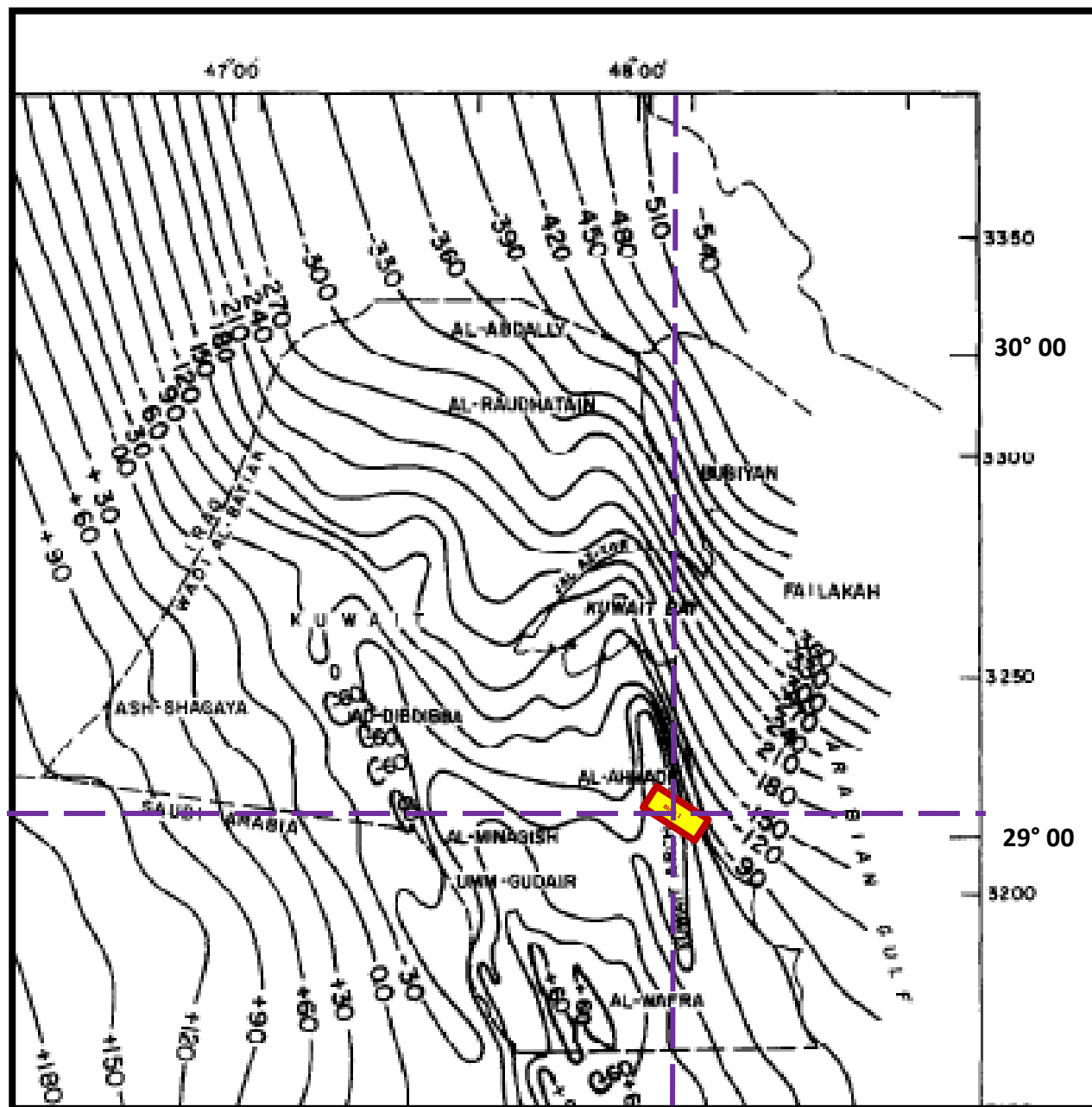
Figure 17: Subcrop of the Mishrif Unconformity. The Wara subcrop is controlled by one well penetration.



Kuwait Stratigraphic Hazards and Drilling Problems



TERTIARY																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							</
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(After Al-Sulaimi et al., 1992)

Structural Contours of top of Eocene Dammam Carbonate Formation.

The map shows present day HC migration paths through the Karstic Dammam Carbonate to the Zero contour area (Sea Level) at Ahmadi Block 1.

The photo below is that of the Dammam Fm. exposures at the crest of the Ahmadi Ridge. The Dammam Fm. is beneath <100 meters of the Miocene Kuwait Group clastic Aquifer at Block 1.

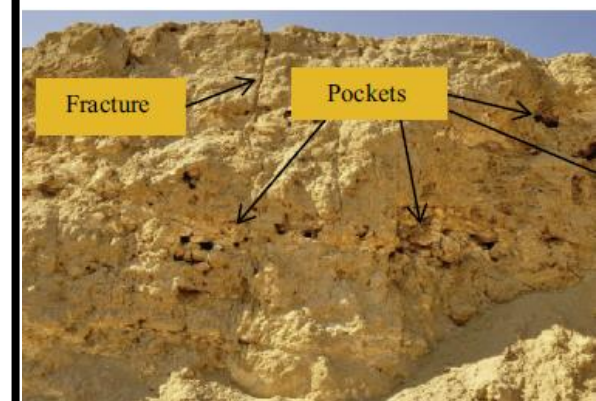


Fig. 14. Evidence of pockets and cavities the Dammam Fm. (After Alkhaledi et al., 2014)

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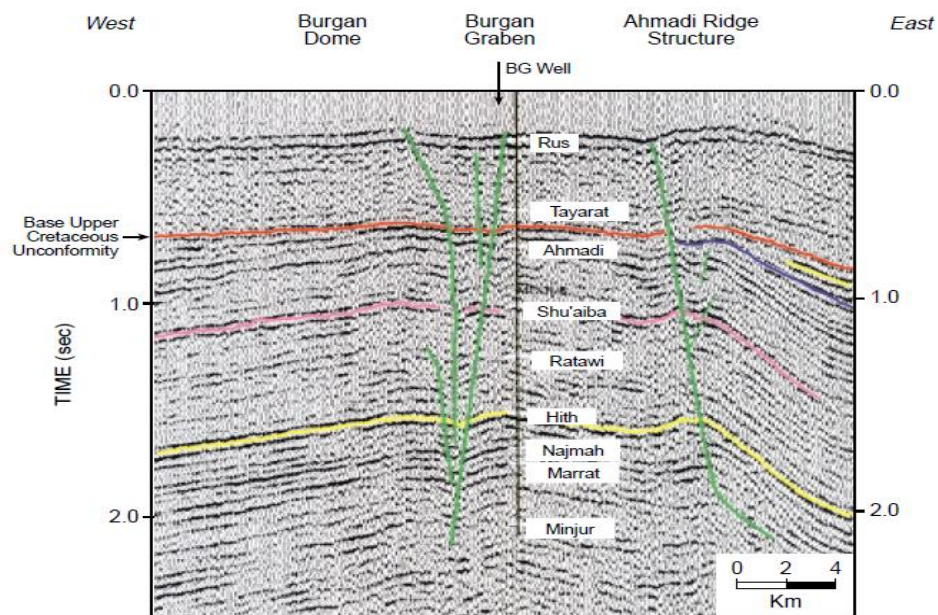
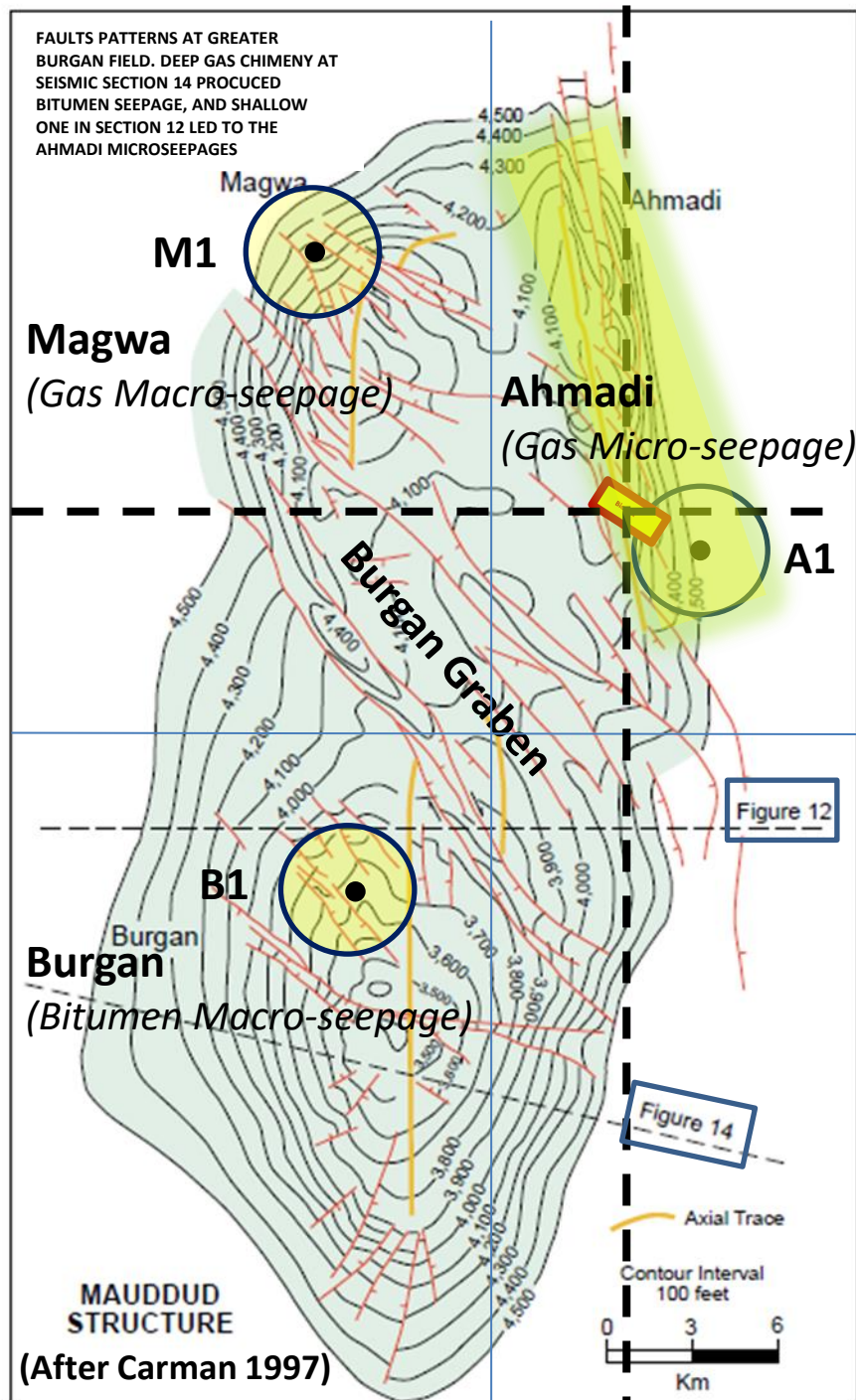


Figure 12 Late Structural Seepage at Ahmadi & Magwa

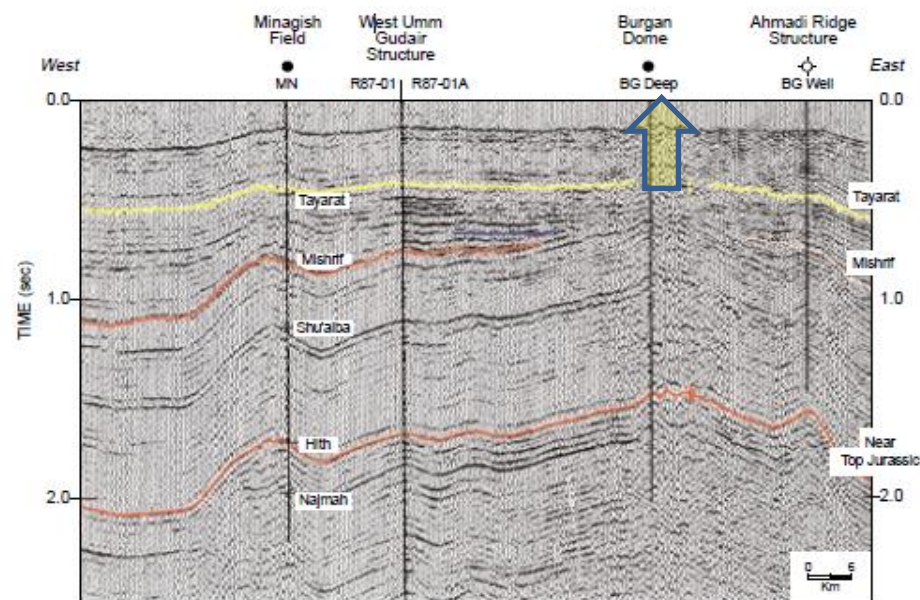


Figure 14 Early Stratigraphic Seepage at Burgan

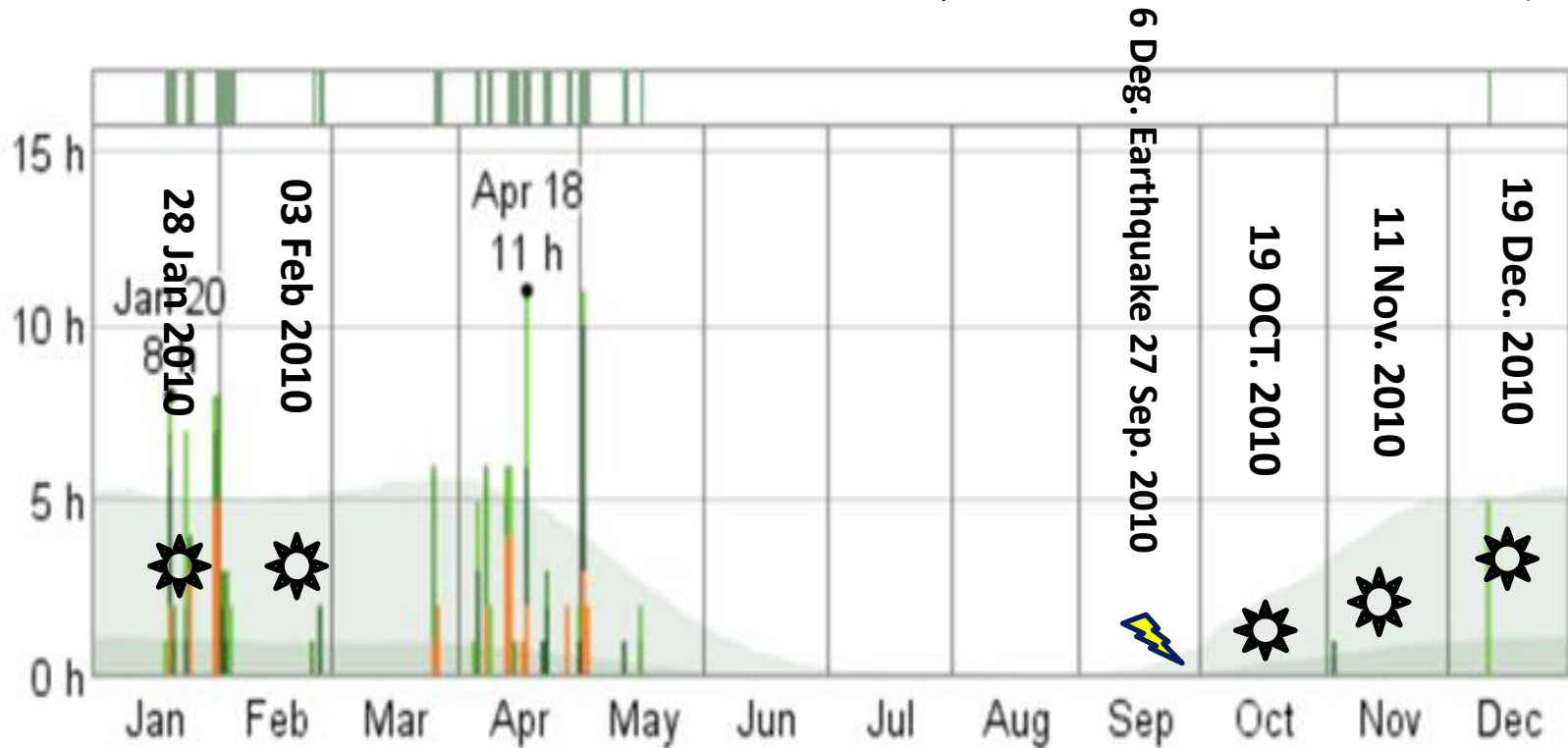
Geologic, Seismic, Climatic and Oil Production Controls on Hydrocarbon Seepages at Al-Ahmadi Town, SE Kuwait



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Daily No. of Hourly Observed Precipitation Reports During 2010 in Magwa, Kuwait

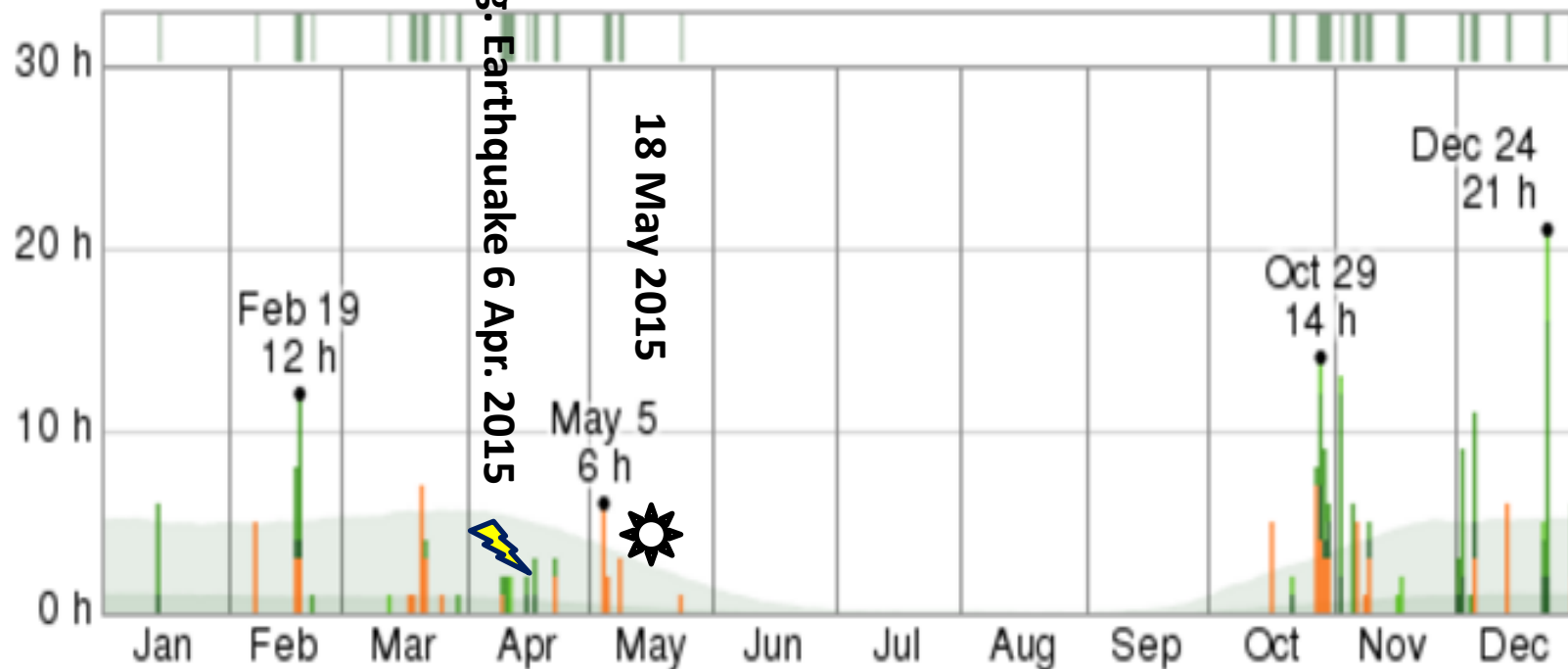
GAS EXPLOSION INCIDENTS HAPPENED ONLY IN THE RAINY SEASONS OF 2010, AND MAY FOLLOW STRONG REGIONAL EARTHQUACK



The daily number of hourly observed precipitation reports during 2010, color coded according to precipitation type, and stacked in order of severity. From the bottom up, the categories are thunderstorms (orange); heavy, moderate, and light snow (dark to light blue); heavy, moderate, and light rain (dark to light green); and drizzle (lightest green). Not all categories are necessarily present in this particular graph. The faint shaded areas indicate climate normals. The bar at the top of the graph is green if any precipitation was observed that day and white otherwise.

Daily No. of Hourly Observed Precipitation Reports During 2015 in Magwa, Kuwait

SAME ASSOCIATION HAPPENED IN 2015



The daily number of hourly observed precipitation reports during 2015, color coded according to precipitation type, and stacked in order of severity. From the bottom up, the categories are thunderstorms (orange); heavy, moderate, and light snow (dark to light blue); heavy, moderate, and light rain (dark to light green); and drizzle (lightest green). Not all categories are necessarily present in this particular graph. The faint shaded areas indicate climate normals. The bar at the top of the graph is green if any precipitation was observed that day and white otherwise.

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6 Richter Scale Earthquake impacted Kuwait on 27 Sept 2010

THE EXTENT AND MAGNITUDE OF 27 SEPT 2010 EARTHQUACK THAT AFFECTED IRAN, KUWAIT AND NEARBY COUNTRIES

5.9 magnitude earthquake 2 km from Kāzerūn, Fars, Iran

6 years ago

UTC time: Monday, September 27, 2010 11:22 AM

Your time: Monday, September 27 2010 2:22 PM

Magnitude Type: mwc

USGS page: [M 5.9 - southern Iran](#)

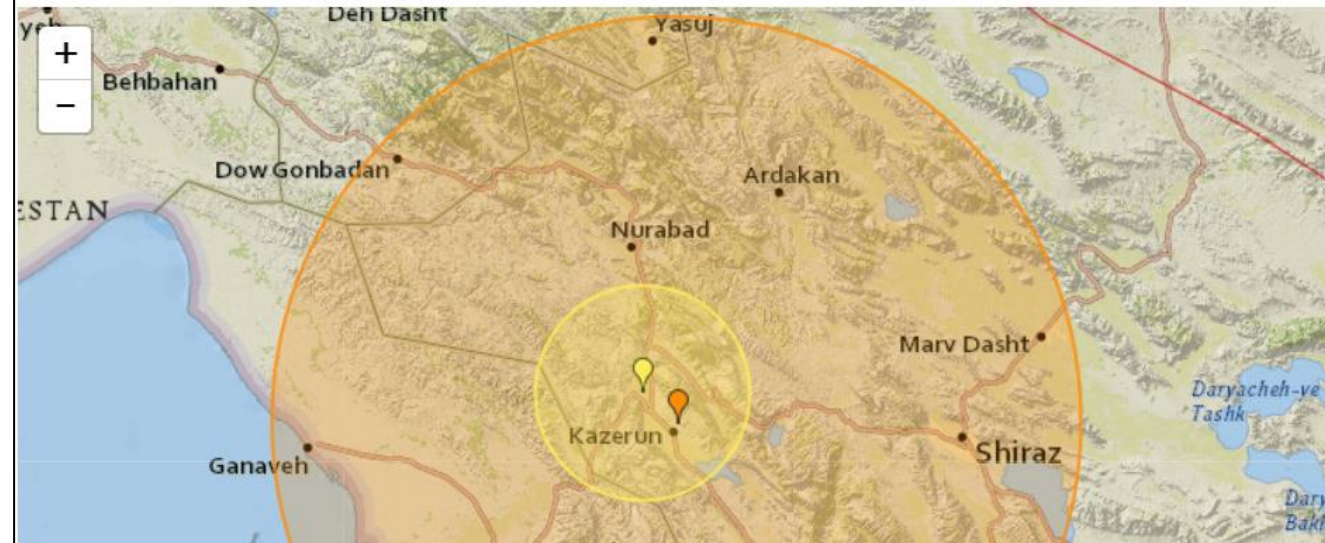
USGS status: Reviewed by a seismologist

Reports from the public: 24 people

 [6 years ago](#) **5.9 magnitude**, 20 km depth
Kāzerūn, Fars, Iran











Aftershocks:

 [6 years ago](#) **4.1 magnitude**, 36 km depth
Kāzerūn, Fars, Iran



Possible Earthquake induced Increase in Gas Seepage Incidents in Ahmadi around 27 Sept 2010 and 6 April 2015

AHMADI GAS EXPLOSION INCIDENTS HAPPENED ONLY IN THE RAINY SEASONS OF 2010, AND MAY FOLLOW STRONG REGIONAL EARTHQUACK.

19 Dec 2010		Dec
11 Nov. 2010		Nov
19 OCT. 2010		Oct
6 Deg. Earthquake 27 Sep. 2010 		Sep
4 Deg. Earthquake 4 Aug. 2012 		Aug
		Jul
		Jun
18 May 2015		May
4 Deg. Earthquake 6 Apr. 2015 		Apr
		Mar
03 Feb 2010		Feb
5 Deg. Earthquake 30 Jan 2016  28 Jan 2010		Jan

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A 100 day survey revealed that Ahmadi Ridge is elevating while Magwa and Burgan Domes are subsiding.

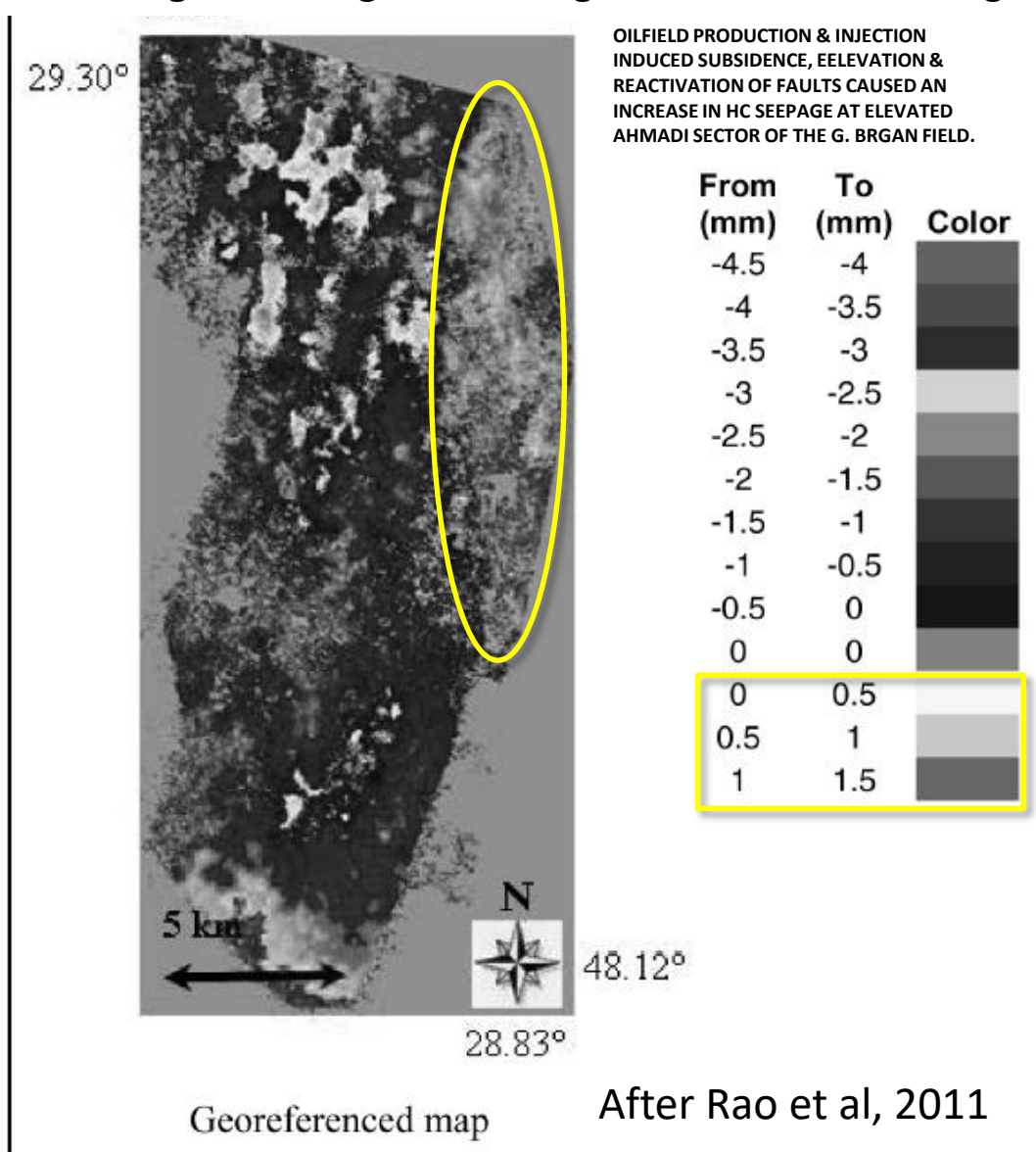
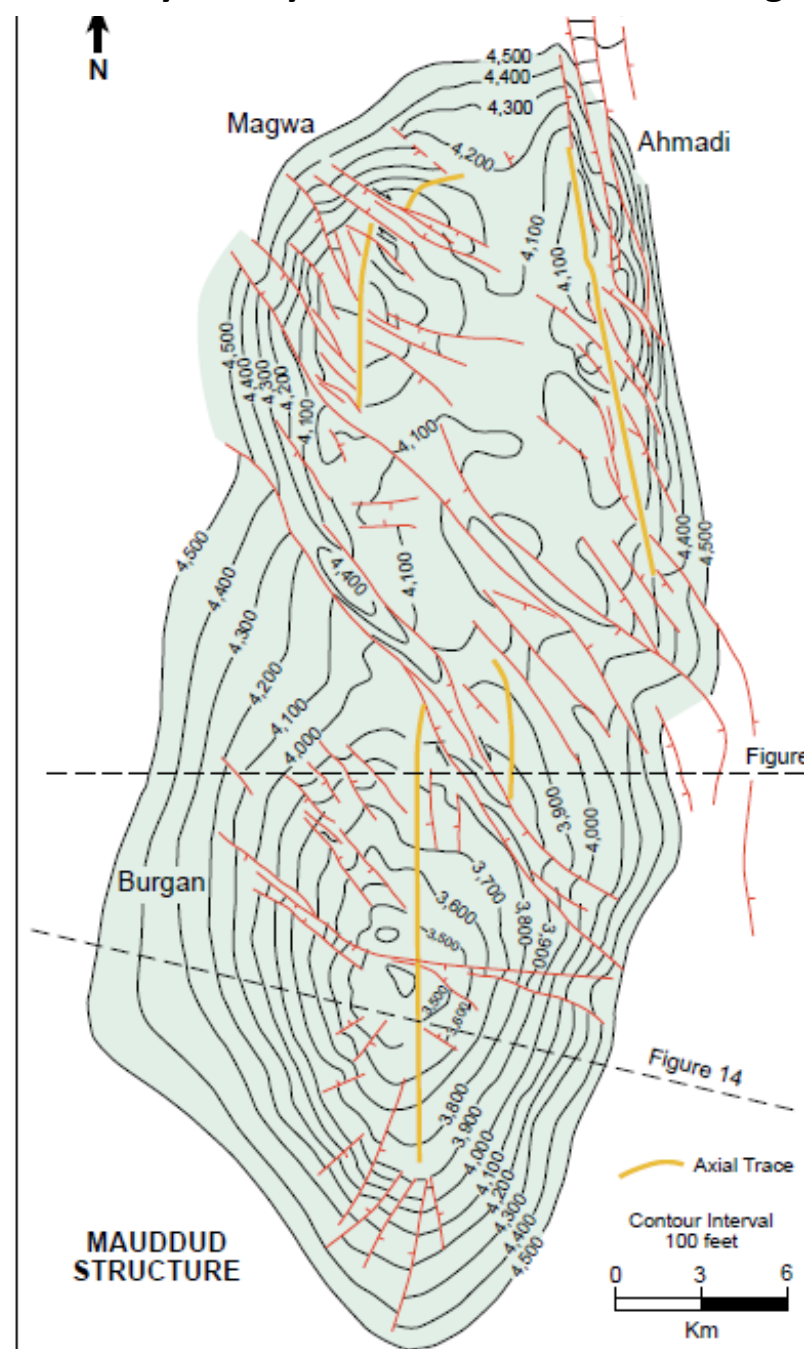


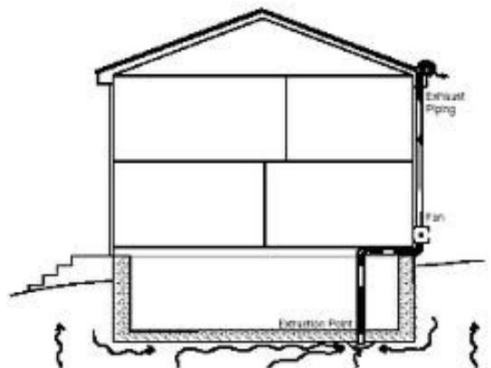
Fig. 22. Subsidence image of Greater Burgan Oil Field generated through least square technique. Most parts of the study area are free from subsidence. The southern portion shows subsidence of 4 mm/100 days and northern portions shows upliftment of 1 mm/100 days.

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vapor protection of buildings can be found at [USEPA](#) (2001).



Sub-Surface Depressurization to Vent Soil Gas Under a Building



Natural gas seepages will be trapped inside unventilated houses, in the absence of gas seepage mitigating systems.

THE OLD UNVENTELATED HOUSES OF AL AHMADI TRAPS NATURAL GAS MICROSEEPAGES

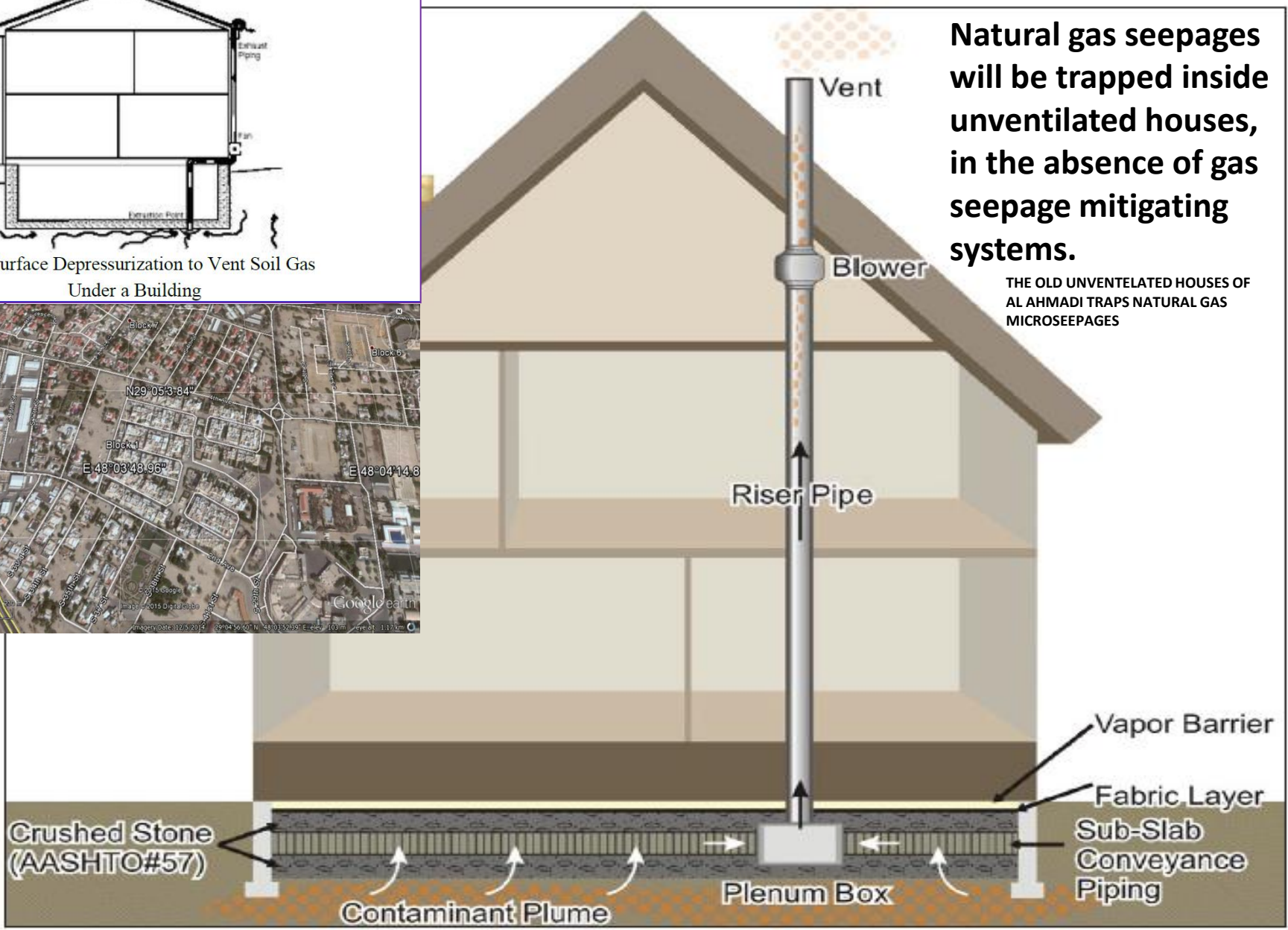


Figure 1. VI mitigation system with a vapor barrier and active SSD.

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Geologic, Seismic, Climatic and Oil Production Controls on Hydrocarbon Seepages at Al-Ahmadi Town, SE Kuwait



Conclusions

1. Eastern Kuwait is prone to natural gas seepages especially above closed oil trapping subsurface structural highs; such as Bahrah and Ahmadi.
2. Gas seeps are flammable thermogenic Methane (CH_4), with poisonous Hydrogen Sulphides (H_2S) gas.
3. The main cap rocks (Ahmadi Shale) of the main Burgan reservoirs (Burgan Mauddud and Wara Formations) is eroded south of Ahmadi Block 1 at Greater Burgan Field.
4. The shallow minor seal (Rus Anhydrite) is ineffective above the Dammam Formation below Ahmadi Block1.

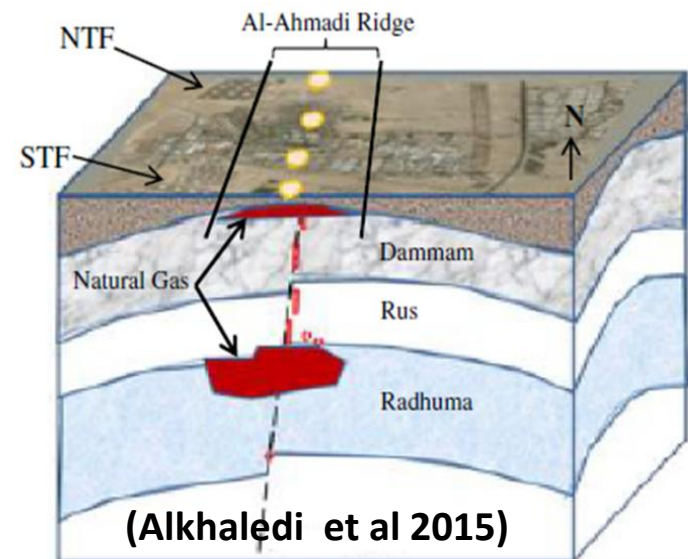
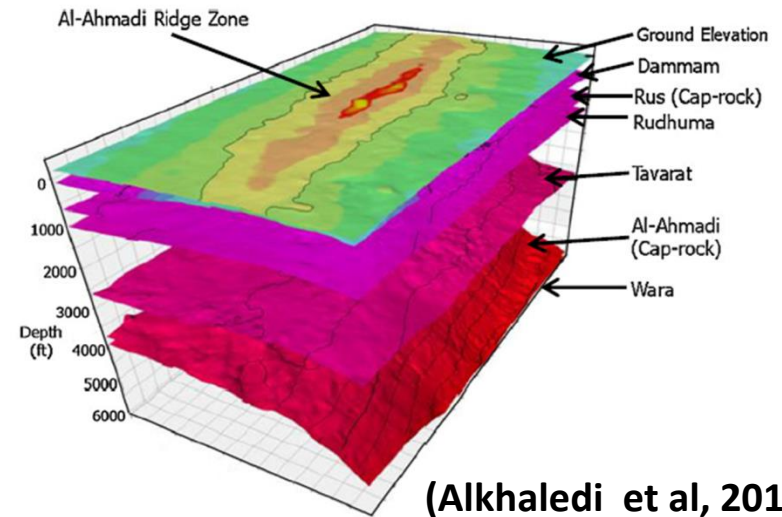


Fig. 9. The Al-Ahmadi ridge zone with north and south tank farms.

Geologic, Seismic, Climatic and Oil Production Controls on Hydrocarbon Seepages at Al-Ahmadi Town, SE Kuwait



1. The exposed and poorly sealed porous, fractured and cavernous Eocene Dammam Limestone structure seeps hydrocarbons through the Kuwait Group from pockets of gas that migrates to the Dammam and Umm Er Radhuma Formations at the structural axis of Ahmadi Ridge from the Burgan reservoirs.



(Alkhaledi et al, 2015)

Fig. 8. Seismic surfaces showing the relative concentrations of natural gas and underground formations.

2. As oilfields subsidence due to HC production, elevation due to water injection and disposal induce seismic fault movements, an increase in the volume of HC seepages is an expected by-products of oil productions in Kuwait and anywhere else.

3. Ahmadi Gas incidents seems to consistently be happening in rainy months, and may follow earthquakes in rainy season (due to rise of water table? and/or low atmospheric pressure pumping?).

Geologic, Seismic, Climatic and Oil Production Controls on Hydrocarbon Seepages at Al-Ahmadi Town, SE Kuwait



Recommendations

- 1. Methane (CH₄) and Hydrogen Sulphide (H₂S) gas detectors and warning systems should be installed in houses, offices and other work places built above the footprints and the peripheries oil and gas fields in Kuwait.**
- 2. Geotechnical, soil natural gas contents and Environmental site investigations and special gas repellent underlay construction are recommended for future residences, offices, schools, farms and factories in gas seeps areas in Kuwait.**
- 3. “Additional study of the geological structure of Al-Ahmadi is needed to detect local faults and any possible gas movement from fractures for the future. Local authorities must be prepared for similar incidents, which could be more severe than those observed previously. It is highly recommended that Al-Ahmadi residents relocate to a safer location.” (Alkhaledi, et. al., 2015).**
- 4. There is a subtle relationship between regional Earthquakes, rainy months i.e. Low Atmospheric Pressure (pumping?) and Gas seepage incidents in Ahmadi which ought to be monitored in Kuwait and Arabian Gulf Countries.**