

How pre- and syn-Hormuz formations were incorporated into the Zagros salt diapirs and reached the surface?

Gabor Tari¹, Gholamreza Gharabeigli², Abbas Majidi²,
Tam Lovett¹, Ali Asghar Julapour², Ralph Hinsch¹,
Christopher Sellar³ and Walter Kosi¹

¹OMV, Vienna, Austria

²National Iranian Oil Company, Tehran, Iran

³OMV Abu Dhabi, United Arab Emirates

OMV Upstream

This work is based on a joint NIOC/OMV field trip in the Fars region, southern Iran, in February 2018.

Moving more. Moving the future.



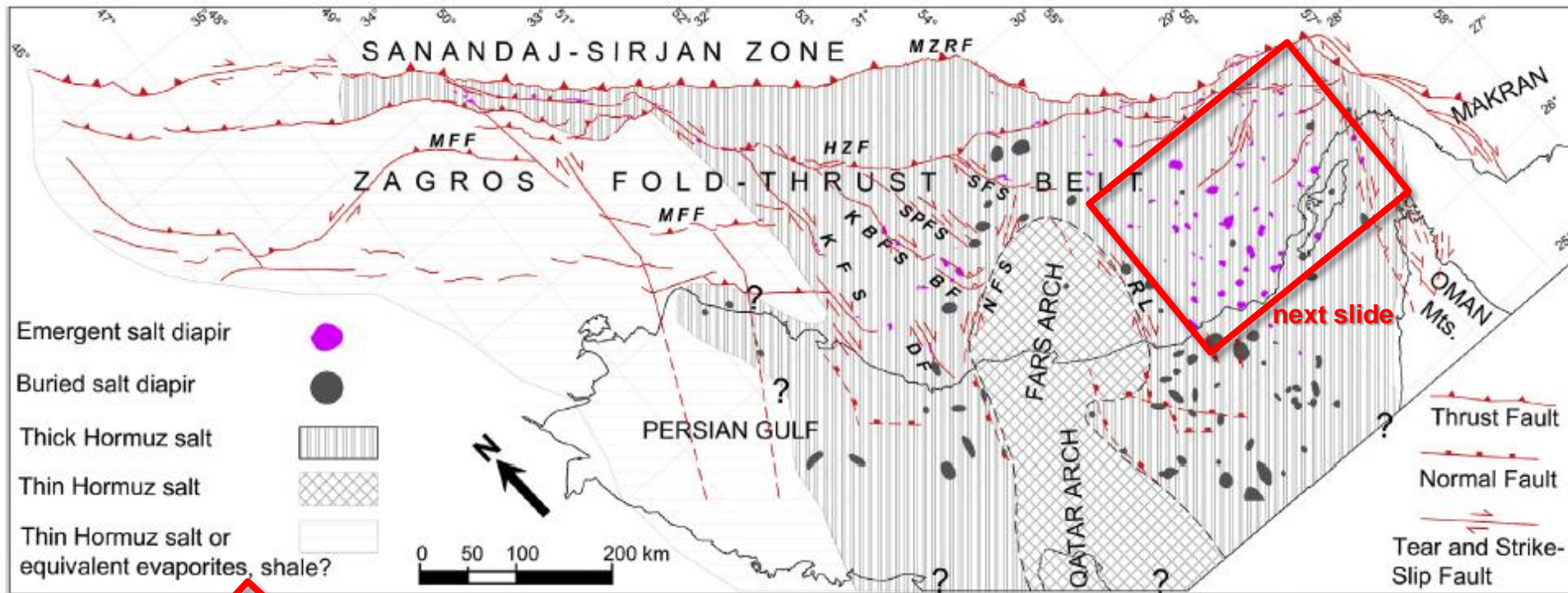
Abstract

The southern Fars region of Iran is a classical and very well-studied area of salt tectonics for more than a century. Our study area is located in the “Simply Folded Belt” of the Zagros Mountains, including the nearby offshore of the Persian Gulf, and has a large number of well-known salt diapirs. These diapirs, composed of the infra-Cambrian Hormuz evaporites, have a surface diameter between 2-12 km and may extend vertically beneath the surface down to anywhere between 6-12 km.

In outcrop, the most striking aspect of these diapirs is the very large proportion of non-evaporitic rocks embedded within the evaporites. Also, these extraclasts (or megaclasts) are sometimes very large, reaching even the kilometer scale. We interpret their present-day dominance and ubiquitous „crowding“ in the outcropping apex of any given diapir as quite misleading as to their overall compositional contribution to the diapiric bodies. In our view, their seemingly large proportion in the internal make-up of the diapirs should be attributed to the preferential preservation of non-evaporitic rocks exposed on the surface. We argue that the real proportion of overall non-evaporitic rocks within a typical Hormuz diapir may not be more than 5-10%. Nevertheless, given their typical lithologies composed of crystalline basement, Eocambrian carbonates and sandstones with very high seismic velocities on the order of 5,000-5,500 m/s, the megaclasts may make the „dirty“ salt faster than the typical 4,500 m/s velocity of a typical “clean” rock salt sequence. These distinct crystalline and poorly dated Lower Paleozoic carbonate and clastic rocks appear to have analogue formations outcropping only very far from the study area, like in Central Iran.

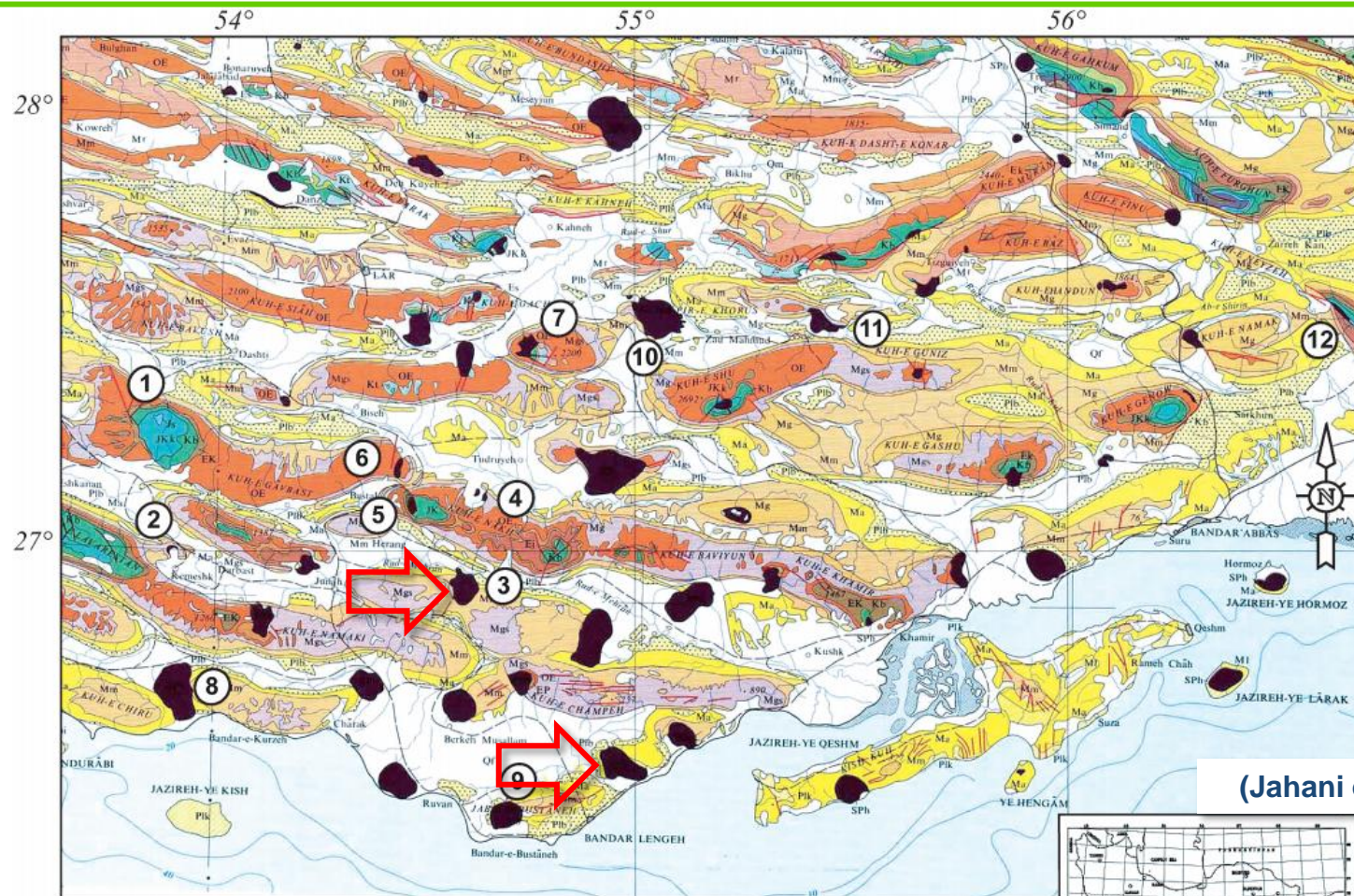
Importantly, as reported by others earlier, we have not found any evidence for the presence of post-Hormuz (i.e. post-Cambrian) host-rock lithologies incorporated into the diapiric material. Therefore, the strikingly selective nature of the extraclast lithologies within the diapiric bodies points to their original intra-Hormuz stratigraphic position. During Cenozoic diapirism, these infra-Cambrian Hormuz “stringers”, also including some pre-rift basement lithologies, were selectively incorporated into the ascending evaporite material as megaclasts and were carried to the surface from large depth. Therefore, one of the important conclusions of our study is that the various Hormuz intra-salt lithologic units must have deposited in a wide-rift extensional setting.

Extent of the Late Precambrian-Early Cambrian Hormuz salt

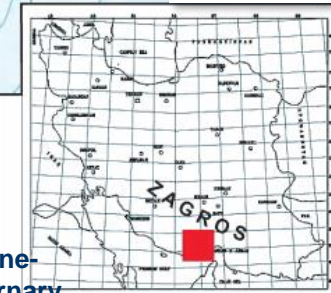
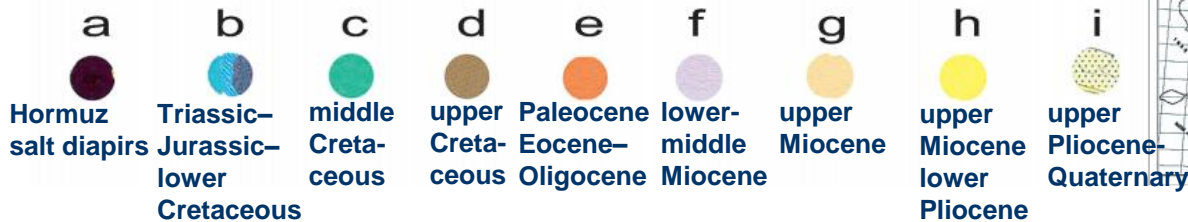


(Jahani et al., 2007)

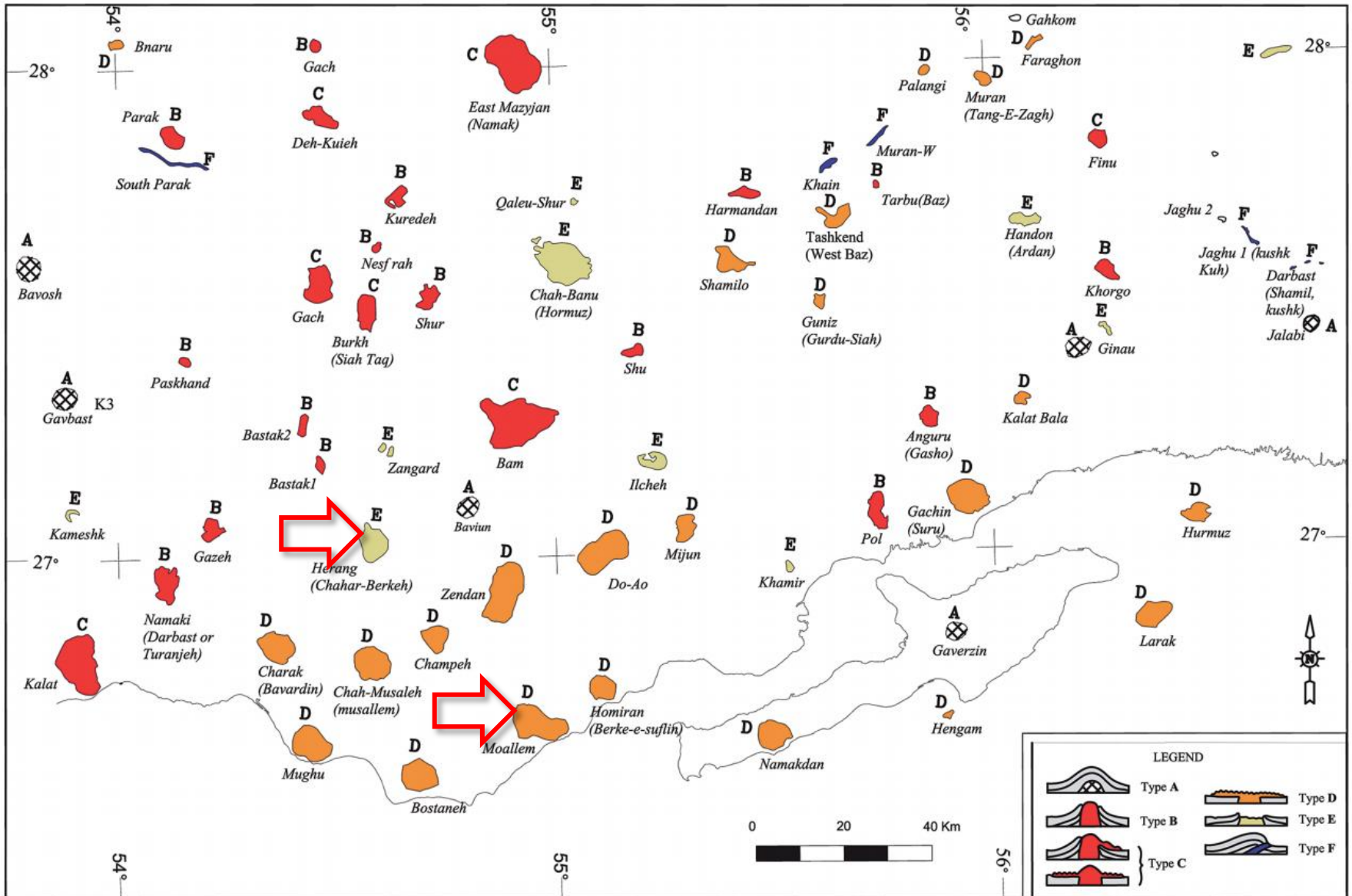
Geologic map of the Fars region of the Iranian Zagros



(Jahani et al., 2007)



Diapir classification by Jahani et al. (2007)



Stratigraphy and the relative position of the evaporites in the Fars region of the Zagros

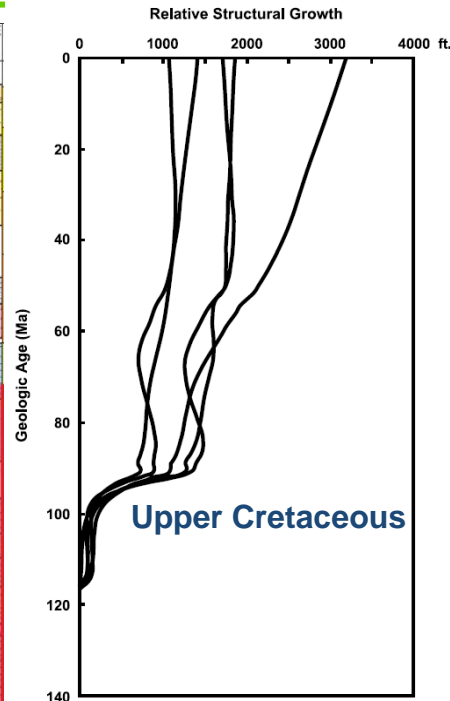
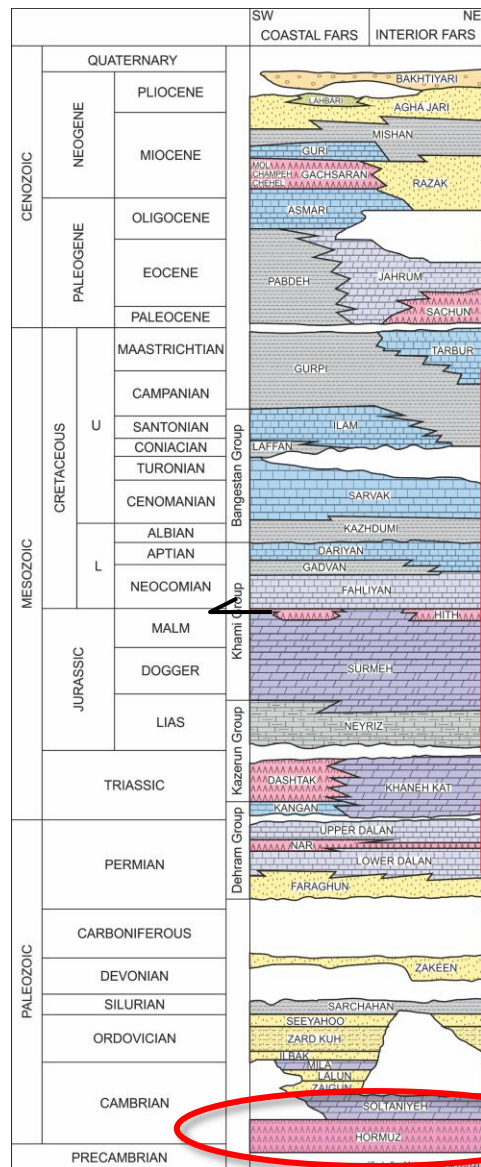
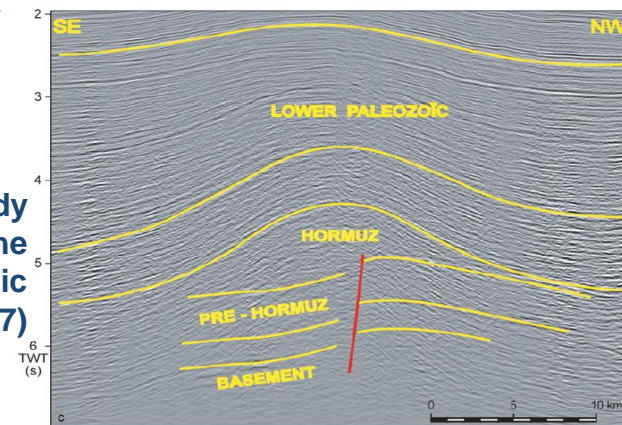


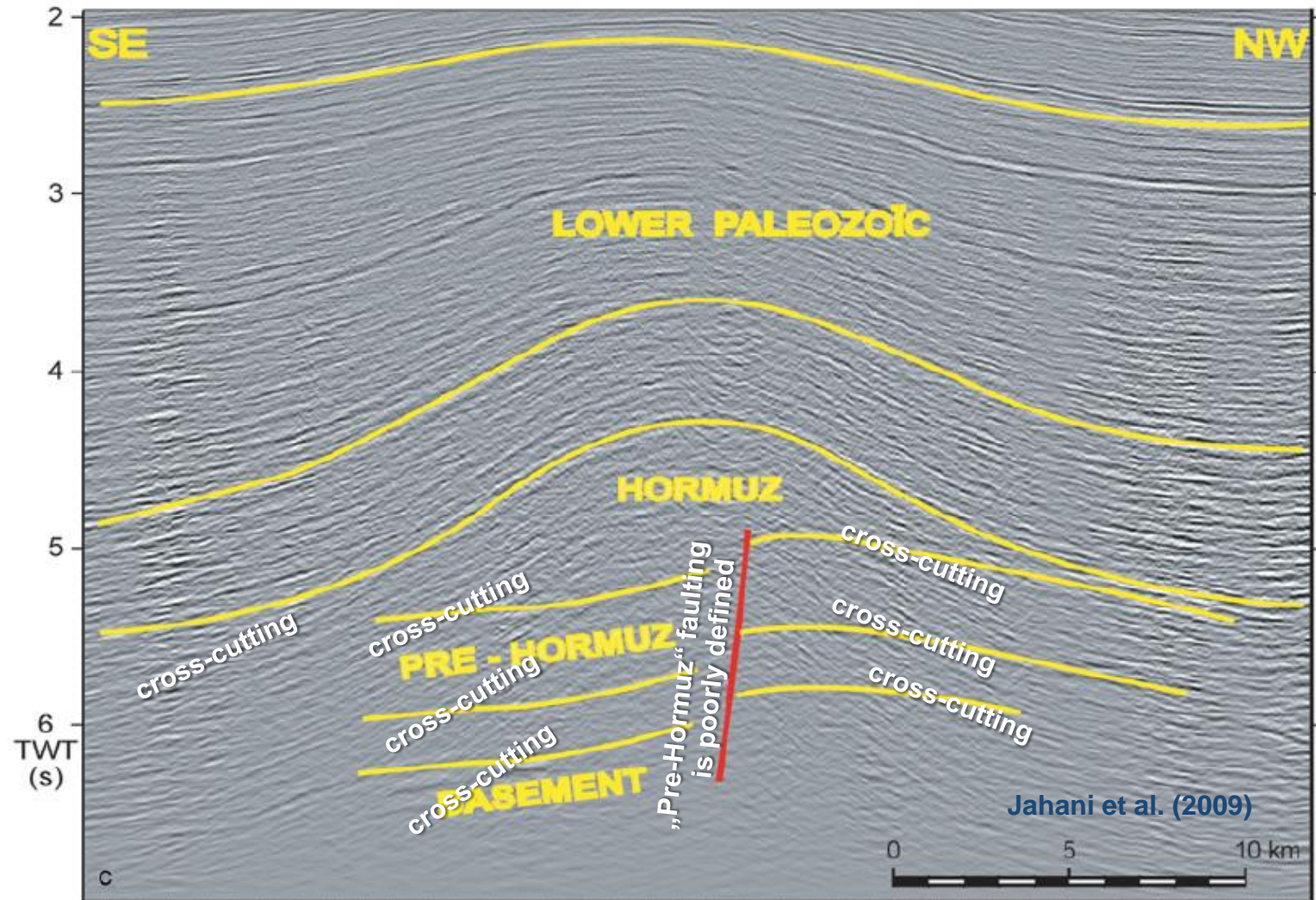
FIGURE 7. Relative structural growth of dome structures offshore the U.A.E. The curvature was estimated from sediment thickness changes on seismic sections. Note that the doming was most profound between 100 and 90 Ma.

Yamada et al. (2005)

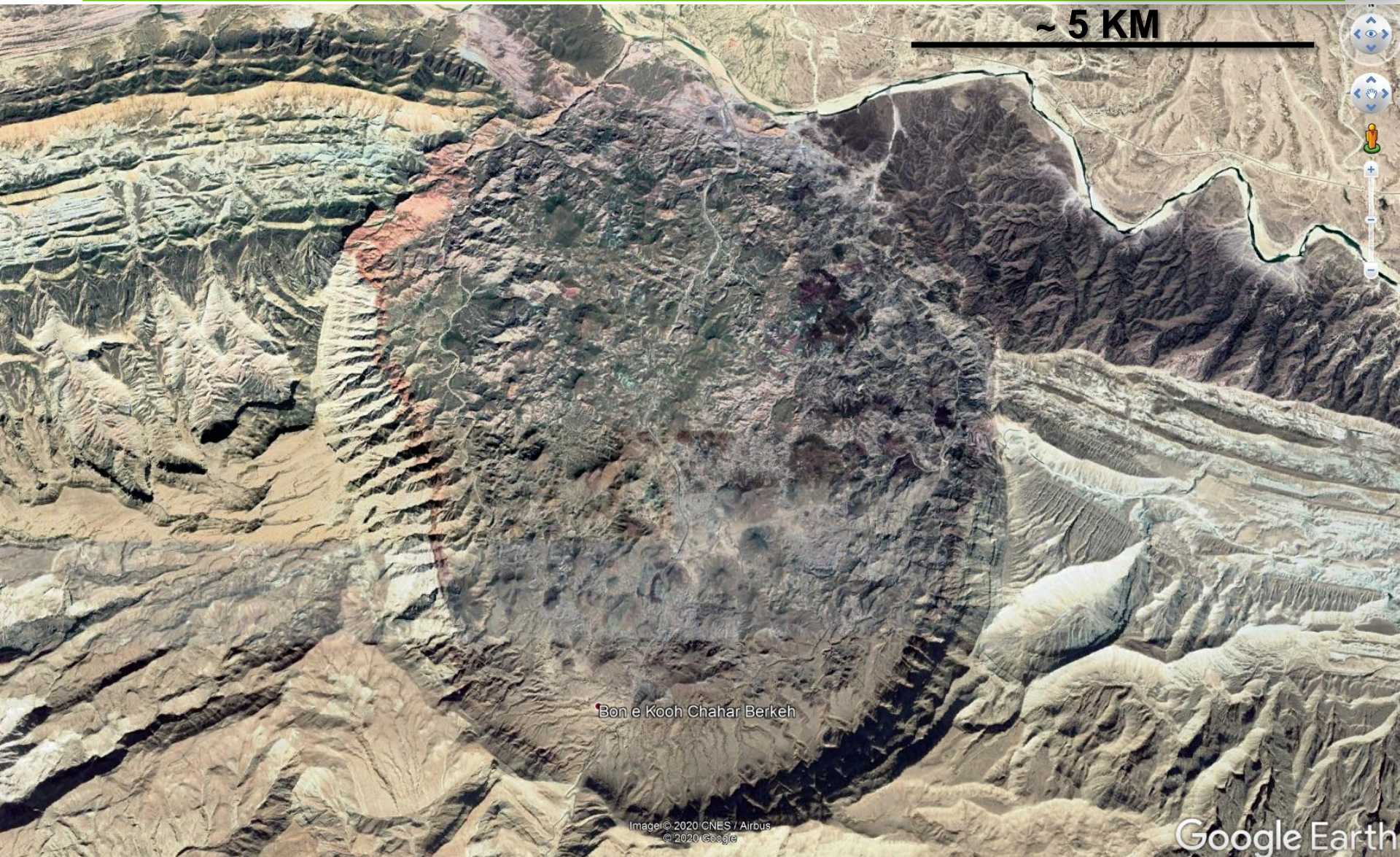
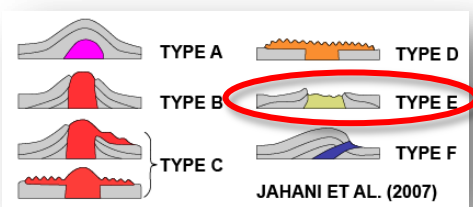
Pillowing already started during the Early Paleozoic (Jahani et al., 2007)



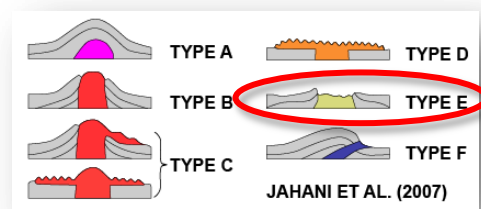
The challenge of mapping the deep Hormuz salt



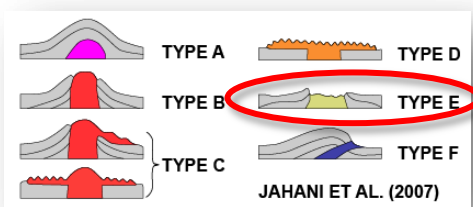
Herang Diapir (Type E, per Jahani et al., 2007)



Basement clasts within Herang diapir



Very large megaclast within Herang diapir



**Most dominant lithology of megaclasts:
magenta to reddish/brownish sandstone
(regarded as the Cambrian Lalun
Formation, by analogy)**



Overtaken megaclast! DZ age dating attempt failed



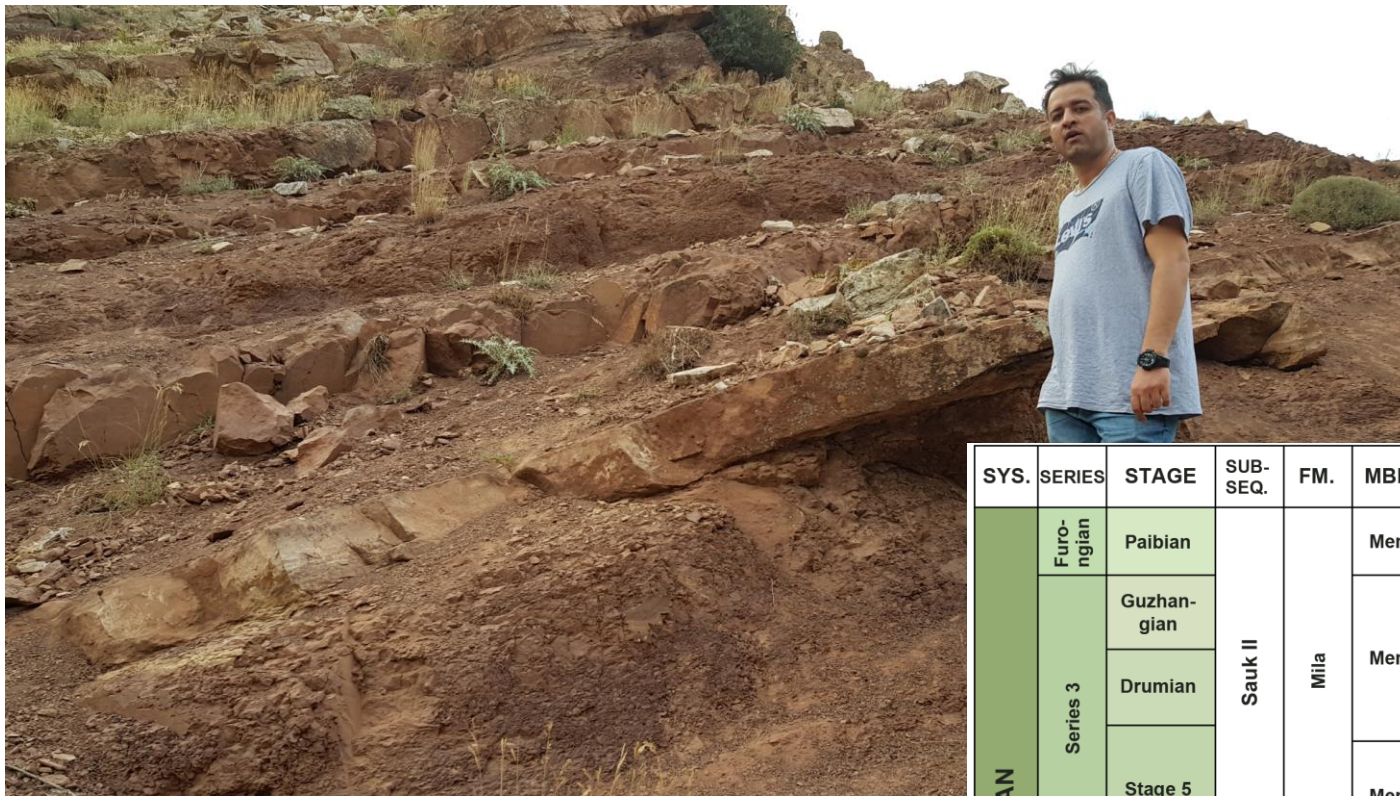
Interpretation:

Fining upwards m-scale cycles with sharp bioturbated bases may represent fluvial, estuarine or tidal depositional environments

An attempt was made to get detrital zircon ages out of this rock... however, failed.

The sample was composed of clay to silt fraction minerals (mainly below 30 μm) which stick together as aggregates mainly by an iron coating.

Cambrian Lalun Formation, sampled near Tehran



Lasemi et al.
(2017)

SYS.	SERIES	STAGE	SUB-SEQ.	FM.	MBR/UNIT	LITHO-LOGY	TRILOBITE ZONE
CAMBRIAN	Furo-gian	Paibian	Sauk II	Mila	Member 3	Prochuangia Palaeadotes-Torifera	
		Guzhan-gian			Member 2	Chelidono-cephalus Iranoleesia	
	Series 3	Drumian			Member 1		
		Stage 5					
		Stage 4			Quartzite Shale Sandstone		
	Series 2	Stage 3	Upper Sauk I	Lalun			
				Bar-Zai-gun			
				Soltanieh	Upper Dolostone		

Shale

Siltstone

Sandstone

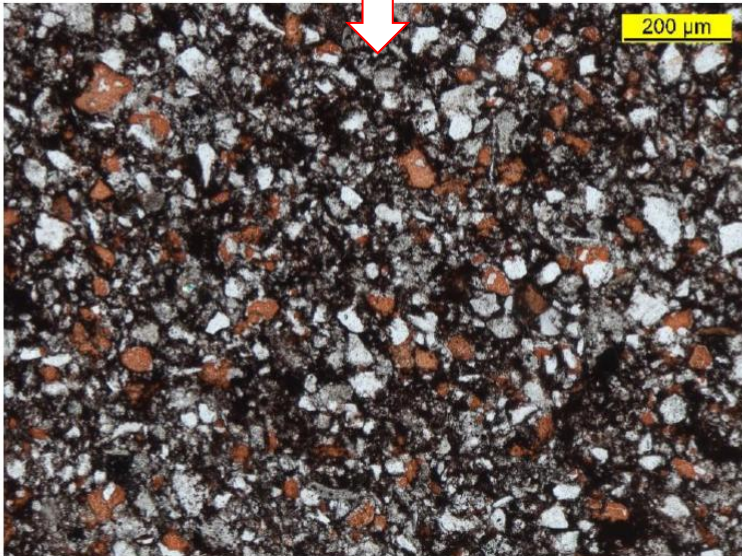
Microconglomerate

Dolostone

Limestone

Unconformity

The Cambrian Lalun Formation is indeed lithologically very similar to the extraclasts found in the Fars diapirs



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Plate 1A Sample IRAN_Zagros
Coarse-grained siltstone with some very fine-grained sand grains.

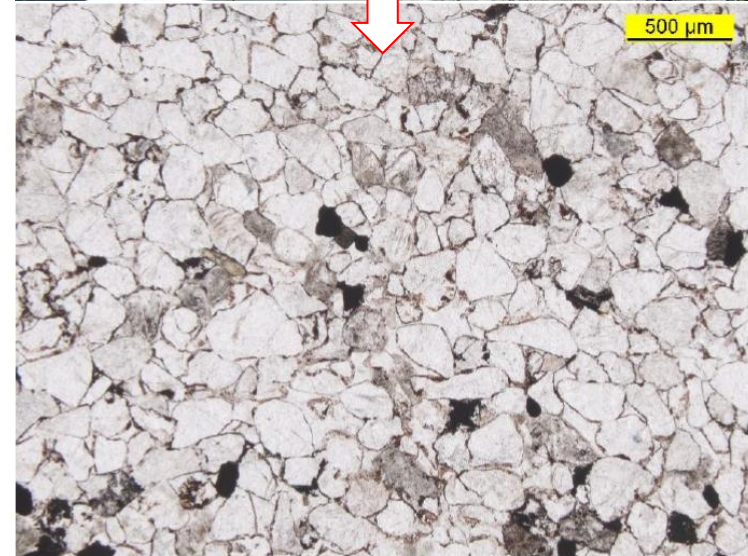
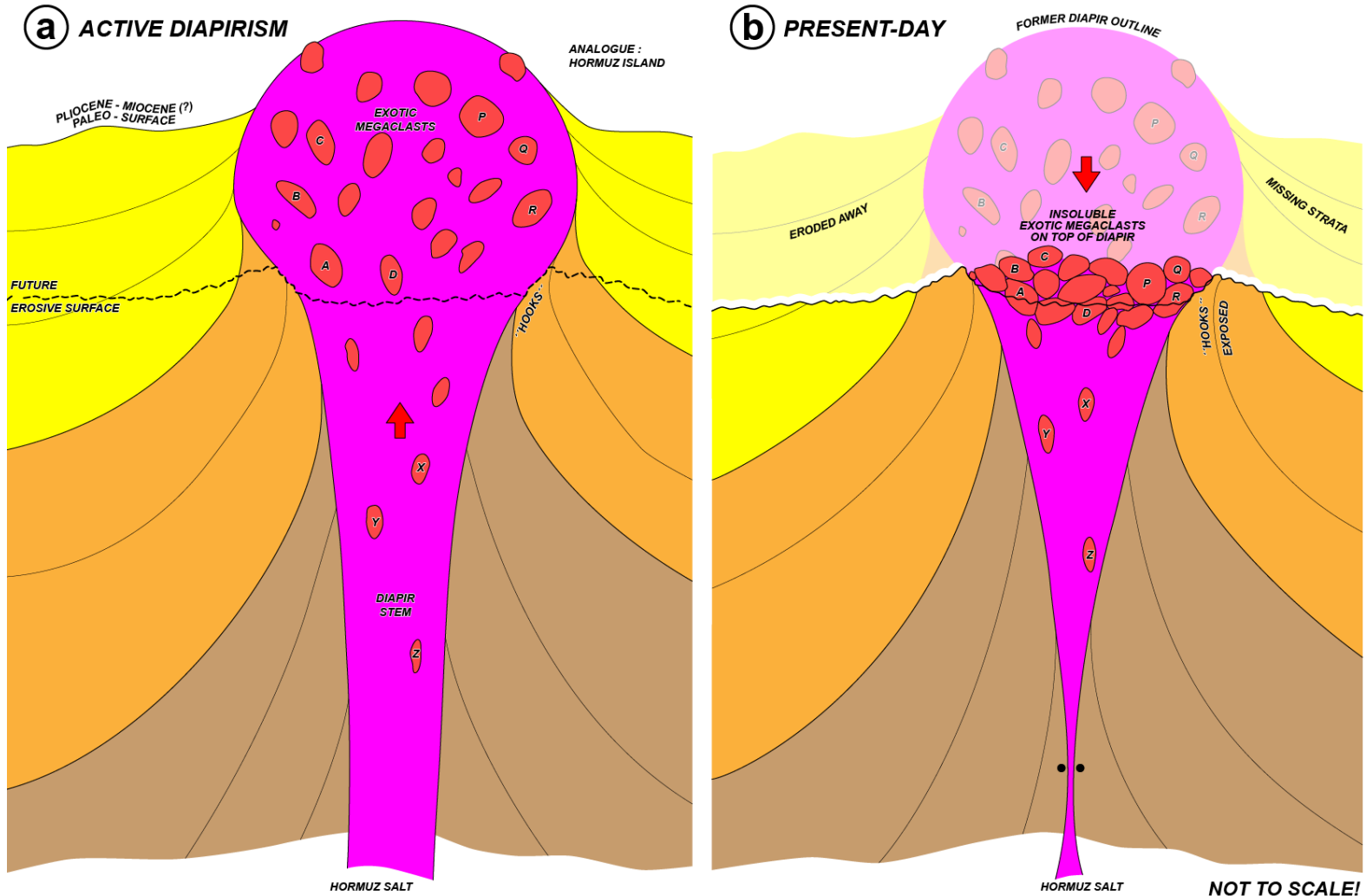
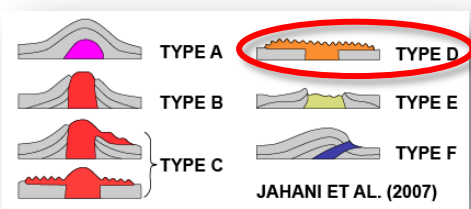


Plate 5A Sample #3
Medium-grained quartz-rich sublitharenite.

Cratered diapirs have numerous insoluble megaclasts: a model for the misleading „crowding“ on the surface...

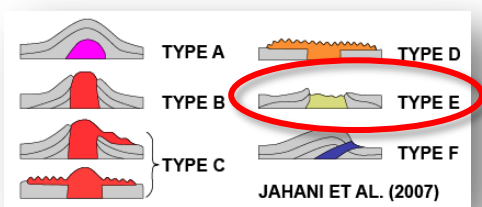


The present-day dominance of megaclasts „crowding“ in the outcropping diapirs is quite misleading. The overall non-evaporitic component within the Hormuz diapir may not be more than 5-10%, however, as these megaclasts make the salt „dirty“, given their overall fast lithology, they make the salt faster than 4500 m/s!

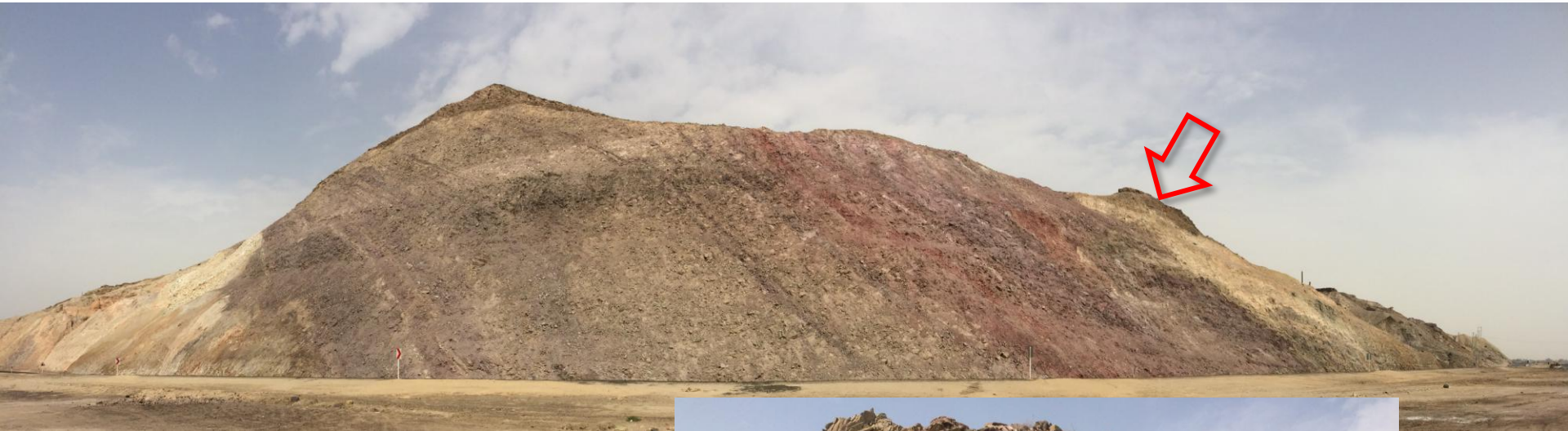


Moallem Diapir (Type D, per Jahani et al., 2007)





Moallem Diapir (Type D, per Jahani et al., 2007)

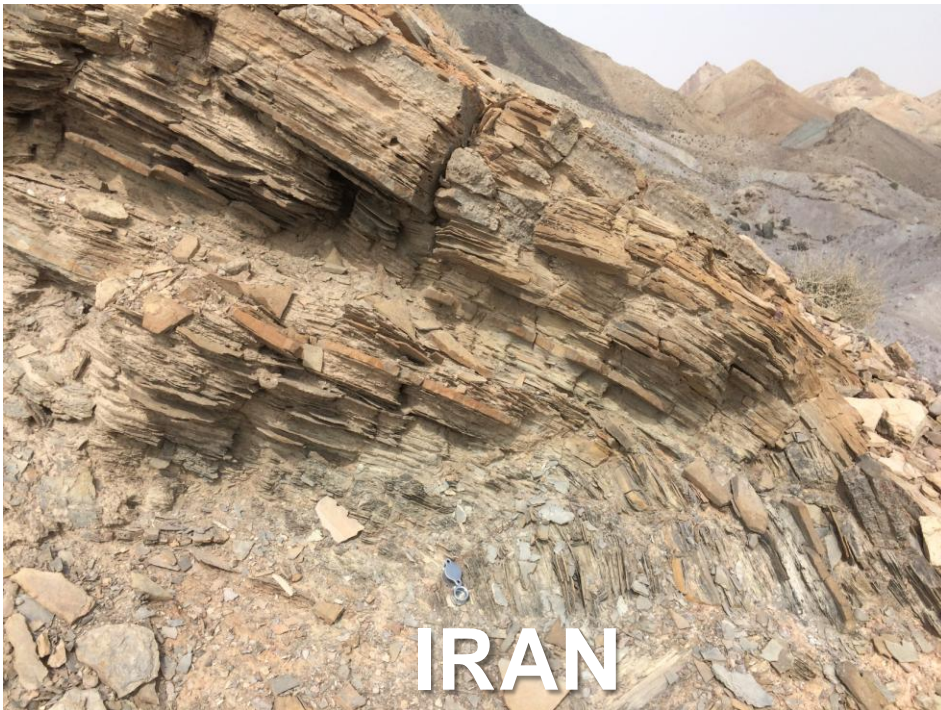


**Moallem Diapir,
exposed in the coastal highway roadcut**

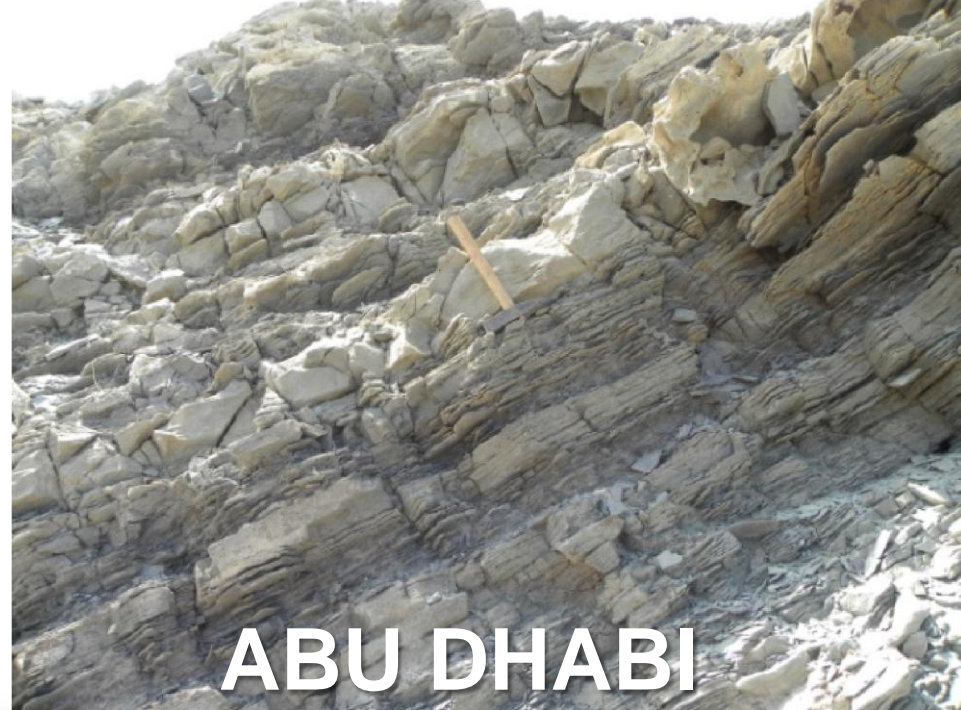


**Megaclast,
with dimensions of about 20x10x8 m**

Megaclast lithologies correlate with UAE diapir material?



IRAN

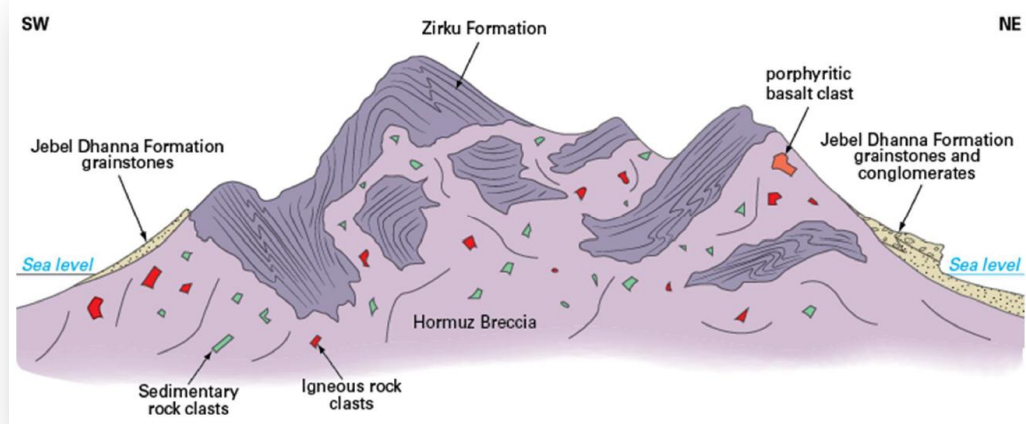


ABU DHABI

Moallem Diapir, exposed in the coastal highway roadcut

These very similar (identical?) looking megaclast lithologies are found about 400 km apart! This underlines the wide-rift nature of the Hormuz syn-rift basin covering a very large area during the „infraCambrian“.

Zirku Island,
United Arab Emirates
Photo and section from
Thomas et al (2012)

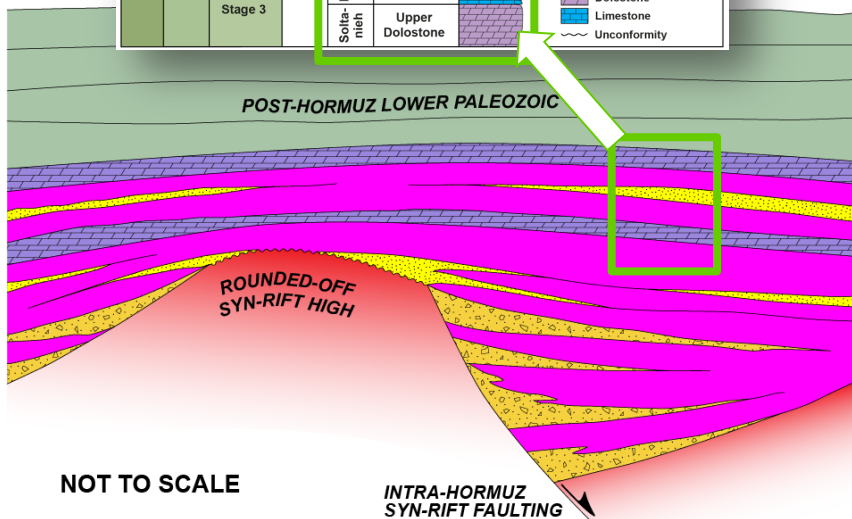


How pre- and syn-Hormuz formations can get incorporated into the salt diapir and reach the surface?

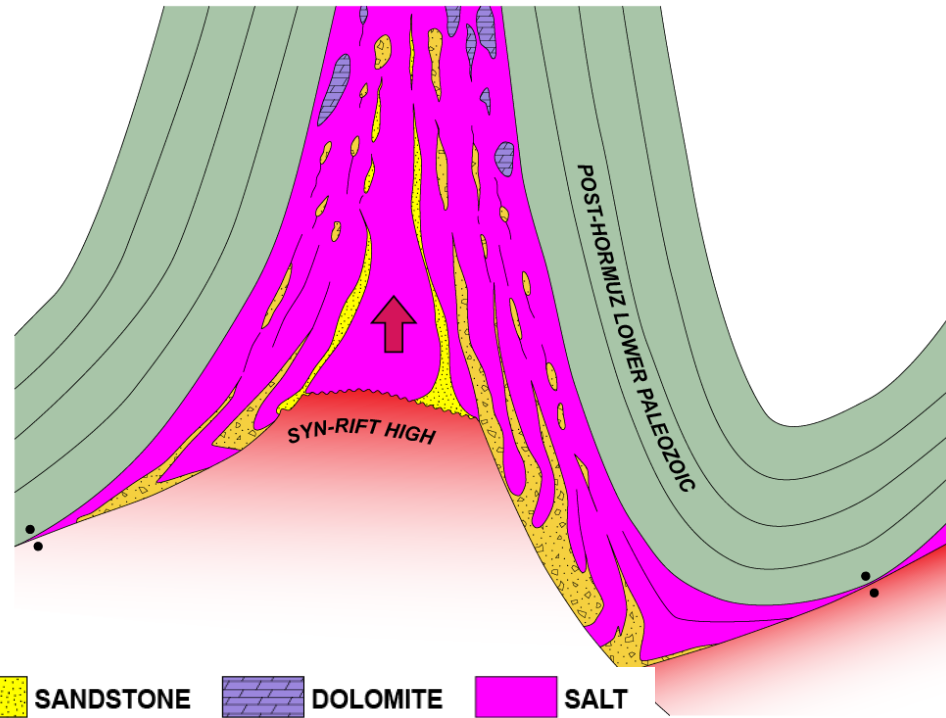
SYS.	SERIES	STAGE	SUB-SEQ.	FM.	MBR/UNIT	LITHO-LOGY	TRILOBITE ZONE
CAMBRIAN	Furongian	Paibian	Sauk II	Milia	Member 3	Prochuangia Palaeodotes-Torifera	
		Guzhangian			Member 2	Chelidonocephalus	
		Drumian				Trilobites	
	Series 3	Stage 5	Upper Sauk I	Lalun	Member 1	Shale	
						Shale	
						Sandstone	
	Series 2	Stage 4			Quartzite	Quartzite	
					Shale	Shale	
					Sandstone	Sandstone	
	Stage 3				Bar-Zai-gun	Bar-Zai-gun	

Lasemi et al. (2017)

Shale
Siltstone
Sandstone
Microconglomerate
Dolomite
Limestone
Unconformity



Note the various extraclast lithologies within the Hormuz evaporitic breccia depicted in the cartoons below. The selective incorporation of the extraclast lithologies into the diapirs point to their intra- and pre-Hormuz position. The clastic and carbonate lithologies may represent the isopic lithofacies to the formations described in northern Iran (e.g. Lalun Formation), some 1000 km(!) to the north.

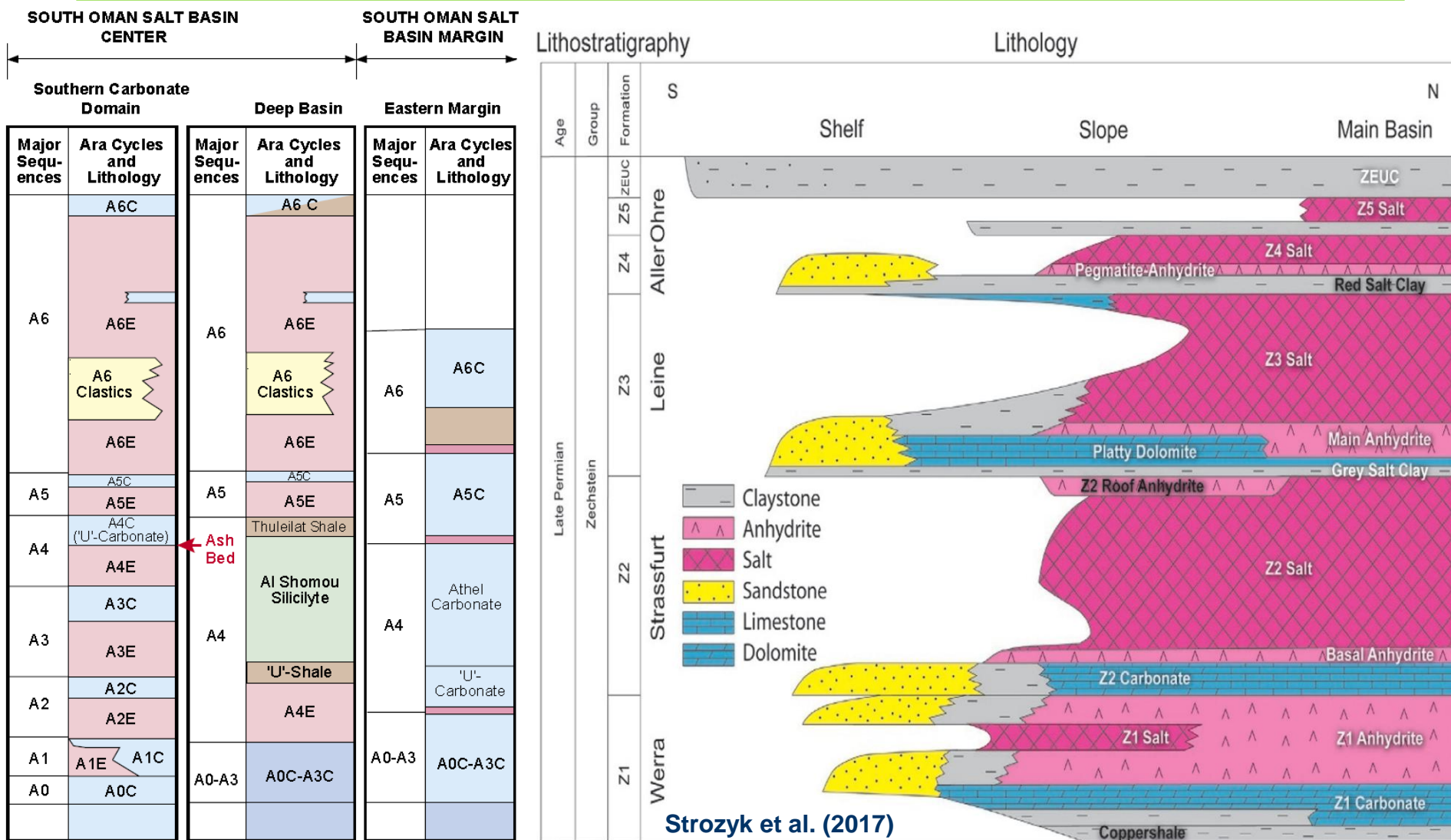


INTRA-HORMUZ
SYN-RIFT FAULTING

BASEMENT TALUS SANDSTONE DOLOMITE SALT

The non-evaporitic components within the Hormuz, including the megaclasts make the salt „dirty“, and faster than the usual 4500 m/s...
It could be as fast as 4800-5000 m/s, and this could be an important parameter for future PDSM work on modern seismic data to be acquired in the broader Zagros area

Analogy between the InfraCambrian Ara (Hormuz) and the Permian Zechstein evaporite sequences



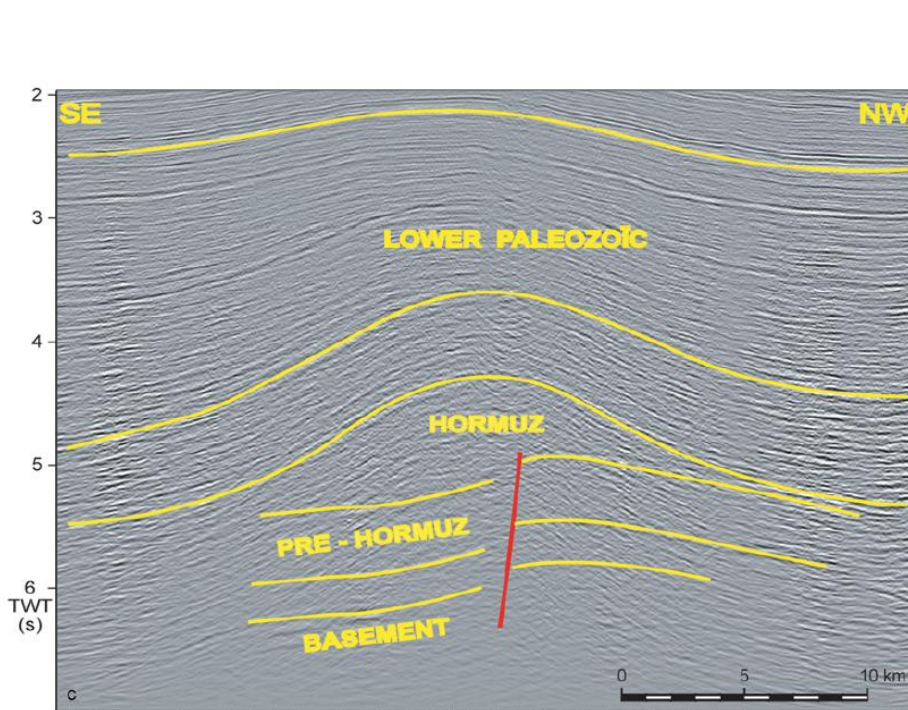
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Halite/Evaporites Platform Carbonates Anhydrite
Shale/Sandstone Silicilyte (Basinal) Basinal Carbonates

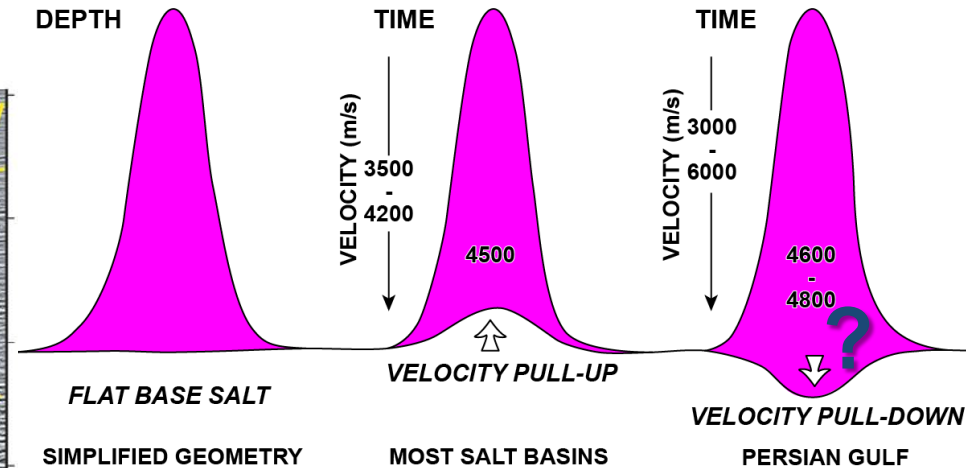
Al-Siyabi (2005)

Note the multiple levels of non-evaporitic lithologies within these evaporite sequences creating the „exotic“ megaclasts

Can we use the velocity pull-up like in most salt basins? Not necessarily...

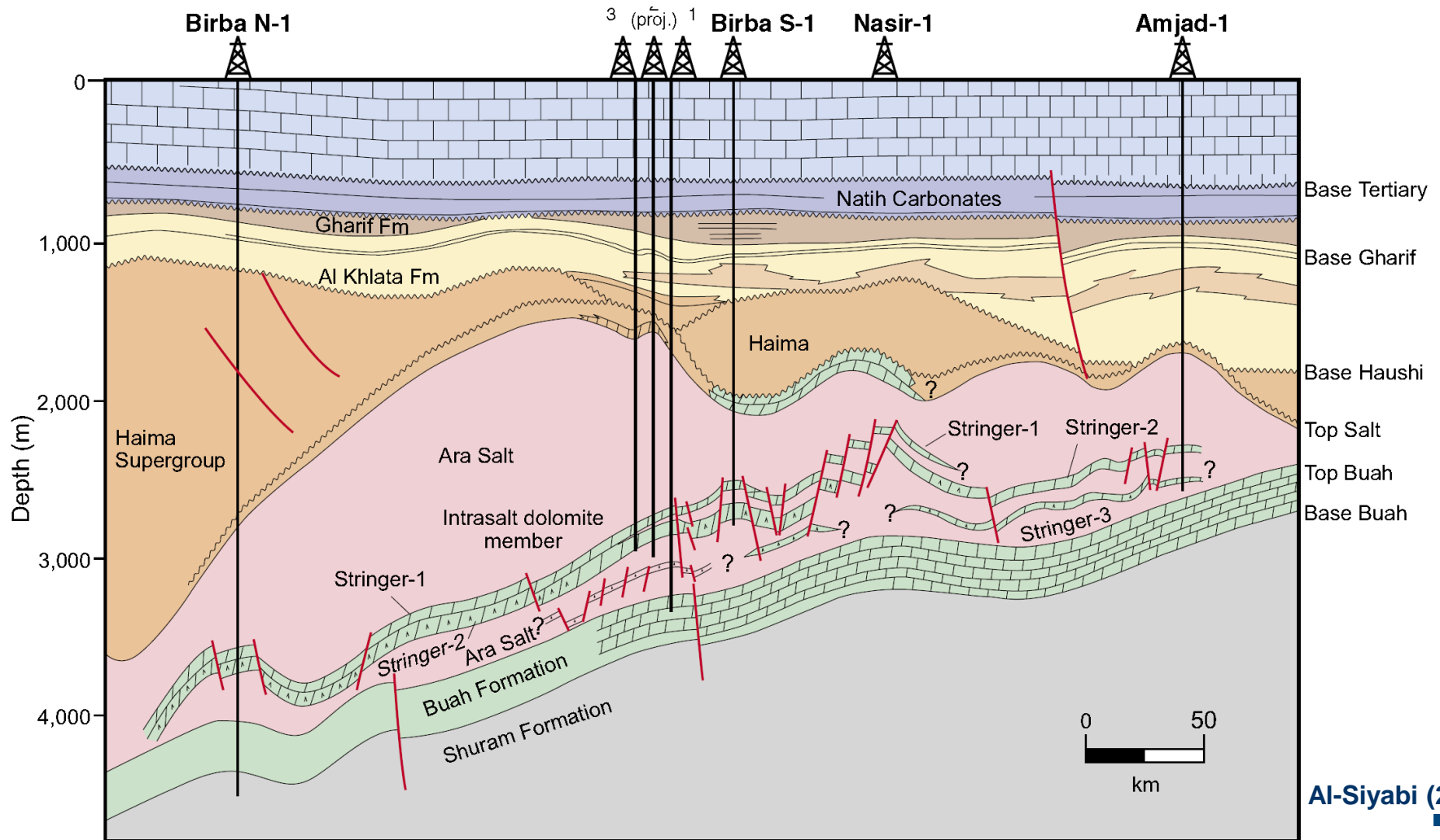


Jahani et al. (2009)



There are no obvious seismic reflection examples of a clear base salt reflector beneath the Hormuz salt features. Given the interval velocity contrast between the Hormuz salt and the surrounding 8-12 km thick post-Hormuz sedimentary succession, actually, a velocity pull-down is expected beneath the salt diapirs once modern 2D and/or 3D seismic data will be available. If there will be a case for a base salt reflector, the depth conversion of the undrilled and uncalibrated deep section could be verified and refined.

Intra-salt stringer analogue from Oman



The depth of the equivalent intra-Hormuz stringer targets is between 8-12 km in the Fars region, therefore this exploration play may not be considered in the Fars region. Whereas stringer materials could be expected in the diapir stems these are more than likely dismembered and therefore cannot be considered as viable exploration targets.