

# **Landsat Exploration of Unayzah Trend, Saudi Arabia\***

**Floyd Sabins<sup>1</sup>**

Search and Discovery Article #20165 (2012)\*\*

Posted August 13, 2012

\*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012

\*\*AAPG © 2012 Serial rights given by author. For all other rights contact author directly.

<sup>1</sup>Remote Sensing Enterprises, Inc., Fullerton ([ffsabins@roadrunner.com](mailto:ffsabins@roadrunner.com))

## **Abstract**

In the late 1980s Saudi Aramco requested Chevron to process and interpret Landsat TM images of the unexplored Central Arabian Arch, which is a vast homocline with regional dips of 1° to 2° and no closed surface structures. The giant fields in the Retained Areas are drape anticlines with very gentle dips that overlie basement faults. We developed a 3-D model illustrating how such structures might be expressed on images of the Arch. We used the model to recognize a number of anomalies on the Landsat images of the Central Arabian Arch. We then checked the anomalies in the field. Next, Aramco conducted seismic surveys that confirmed the model concept. In 1989 the Raghb and Dilam fields were discovered on anomalies that are almost 100 km from the nearest fields. The Unayzah Sandstone (Pennsylvanian and Permian) reservoir produces light, sweet oil, in contrast to the heavy, sour oil of the Arab D (Jurassic) of the Retained Areas. The organic-rich Qusaiba Shale (Silurian) is the source of the oil which migrated upward along the faults that underlie the anticlines. Exploration of other Landsat anomalies was interrupted by Desert Storm, but resumed with several additional discoveries along the “Unayzah Trend”.

## **Reference**

McGillivray J.G., and M.I. Hussein, 1992, The Palaeozoic petroleum geology of Central Arabia: AAPG Bulletin v.76, no. 10, p. 1473-1490.



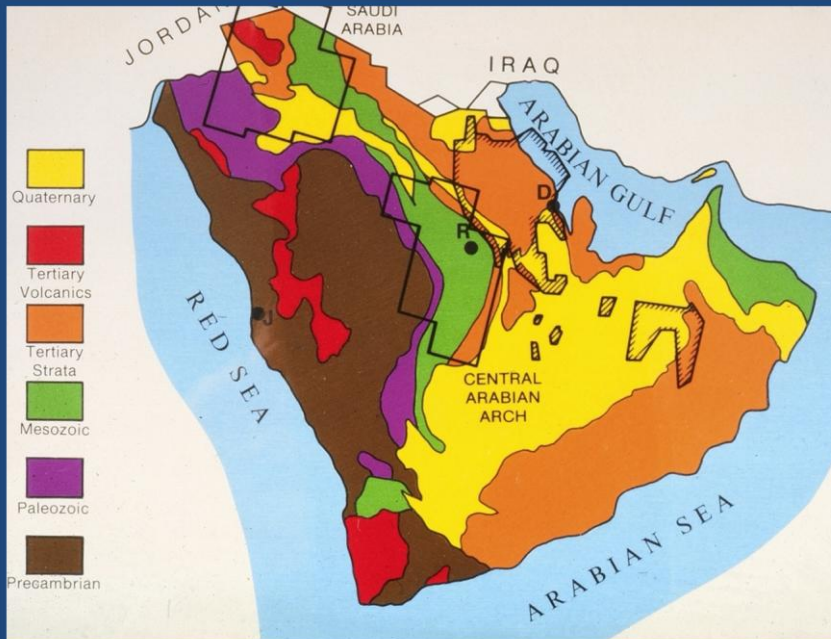
# **LANDSAT EXPLORATION OF UNAYZAH TREND, SAUDI ARABIA**

**Floyd F. Sabins**

**Remote Sensing Enterprises, Inc.**

**[ffsabins@roadrunner.com](mailto:ffsabins@roadrunner.com)**

## Geologic Index Map



Presenter's notes: Index map of Arabian peninsula. Hachured outlines – Retained areas where exploration was confined until late 1980s. D - Dharan and Dammam Dome (first Saudi oil discovery). R – Riyadh, Saudi capitol. Note location of Central Arabian Arch project.

# Natural Color Image From Google Earth



Presenter's notes: Google Earth true color image of Arabian peninsula. D- Dharahn and Dammam dome.

## Central Arabian Arch Mosaic

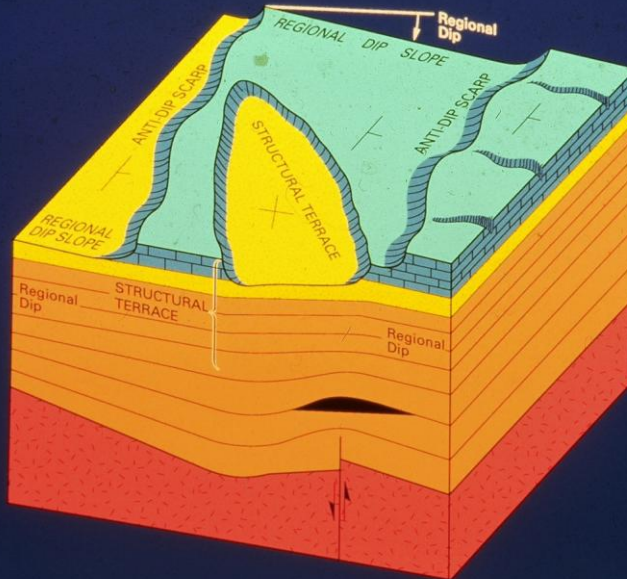
Enhanced-color TM images



Presenter's notes: Central Arabian Arch project area. Enhanced color Landsat TM mosaic. Note very gentle NE and E dip (1 to 2 degrees) of outcrops. >200,000 km<sup>2</sup>

# Model of Drape Anticline

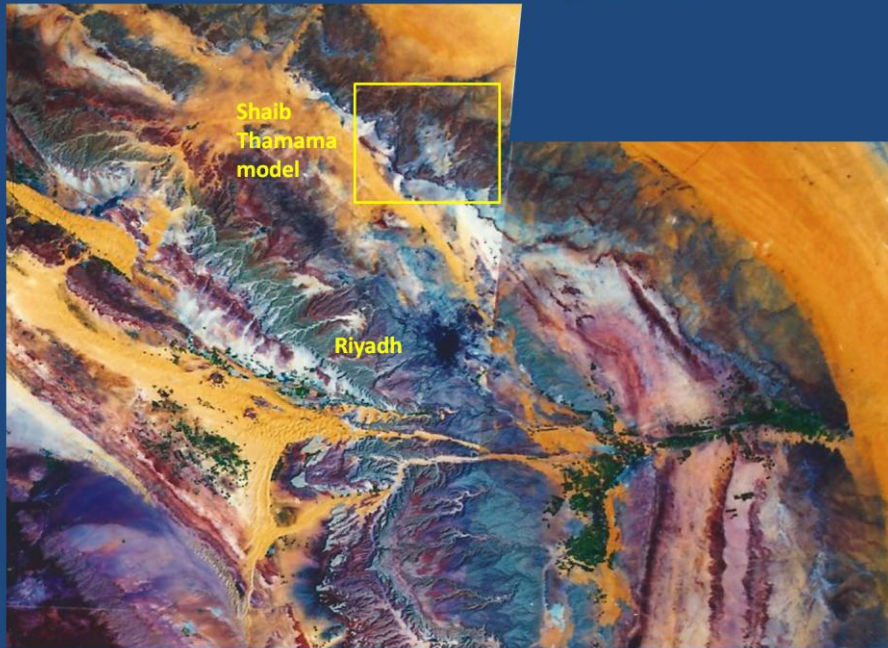
Surface expression is a structural terrace



Presenter's notes: Model of fault-controlled anticlines that migrate upward into structural terraces with geomorphic expression.



## Shaib Thamamah Geologic Model



Presenter's notes: Central Arabian Arch index image. Note northwestward truncation at base of mid-Cretaceous unconformity.

## Shaib Thamamah Geologic Model

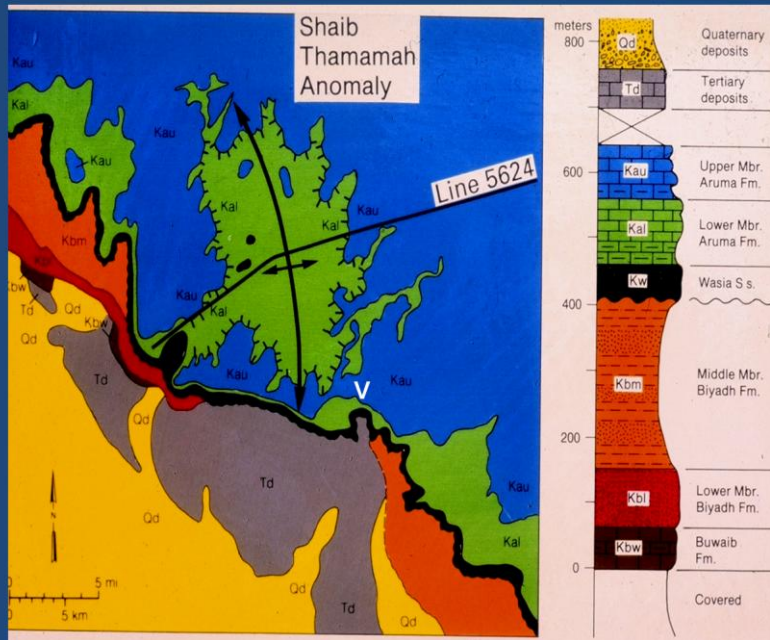


Presenter's notes: Shaib Thamamah anomaly. Gently NE-dipping Upper Member of Aruma Fm. (dark signature) is warped into a structural terrace that is eroded to expose the Lower Member (bright signature).



# Shaib Thamamah Geologic Model

Seismic line acquired to validate model



Presenter's notes: Shaib Thamamah map showing seismic line 5624 that Saudi Aramco acquired to test the geologic model.

# Shaib Thamamah Geologic Model

## View south along regional anti-dip scarps



Presenter's notes: View along south margin of Shaib Thamamah anomaly showing regional anti-dip scarps of Aruma Fm.

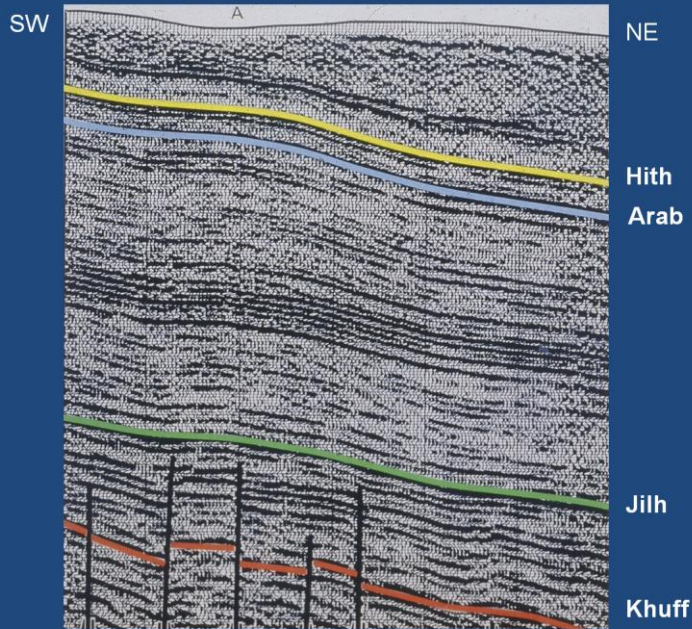
## Shaib Thamamah Geologic Model

View NW across model at anomalous scarps



Presenter's notes: View looking north at Shaib Thamamah anomaly which is a depression floored with nonresistant Lower Member of Aruma Fm. In the distance are anomalous NE-facing scarps of Upper Member of Aruma Fm.

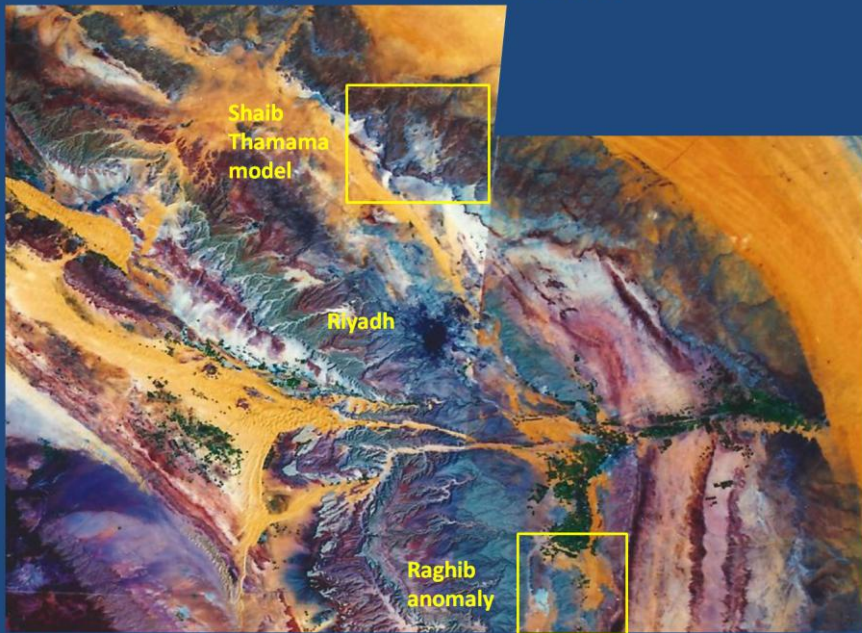
## Seismic Line Across Shaib Thamamah Model



Presenter's notes: Line 5624 across S T anomaly. Regional NE dip is interrupted by structural terrace overlying basement faults. The five faults account for the large extent of the anomaly.



## Raghib Anomaly Location



Presenter's notes: Central Arabian Arch index image showing location of Raghib anomaly.



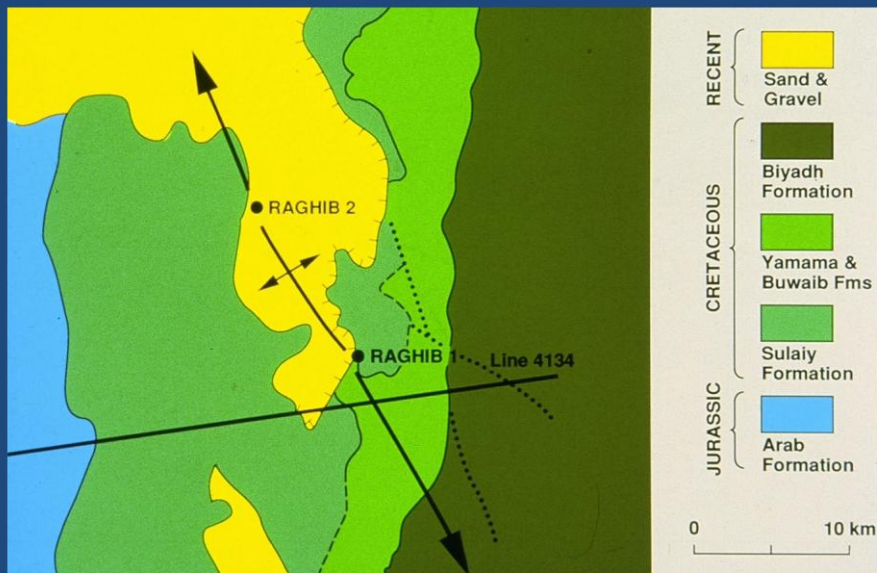
## Raghib Anomaly

West rim  
of terrace  
removed  
by erosion.



Presenter's notes: Image of Raghib anomaly that is an eroded structural terrace within gently east-dipping strata. Anomaly is mantled by windblown sand with yellow signature.

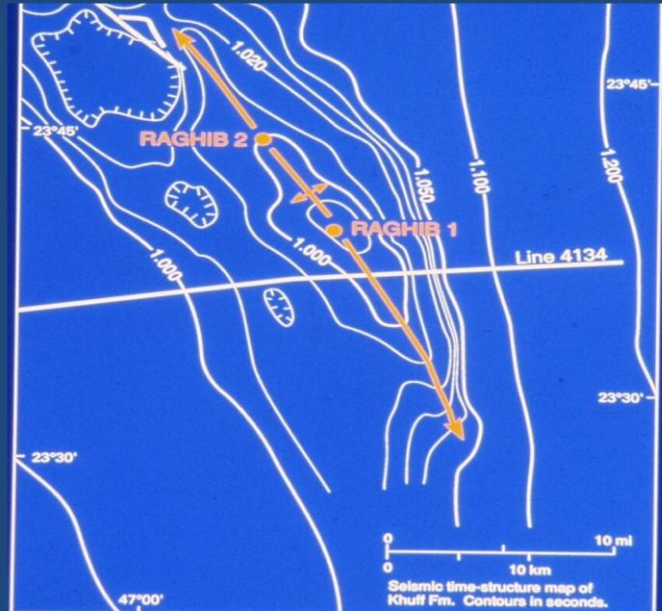
## Geologic Interpretation of Raghib Image



Presenter's notes: Geologic interpretation of Raghib image. Raghib 1 and 2 are discovery and confirmation wells. Note location of seismic line 4134.

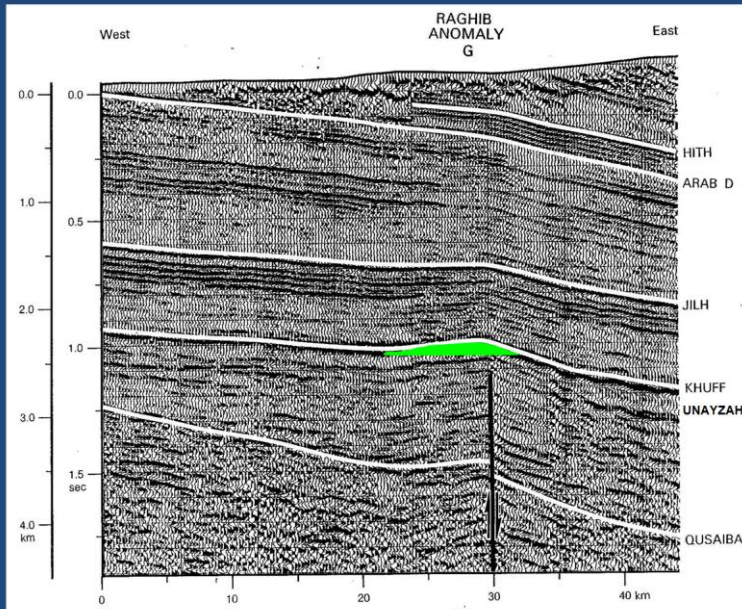
# Raghib Seismic Contour Map

## Top of Khuff Formation



Presenter's notes: Seismic contours (seconds) on top of Khuff Limestone that overlies the Unayzah reservoir sandstone.

# Raghib Seismic Section



Presenter's notes: Seismic line 4134 across Raghib field which is a drape anticline above a basement fault. Oil from the Qusaiba (Silurian) source rock migrated up the fault and was trapped in the Unayzah Sandstone (Permian), which is sealed by the impermeable Khuff Limestone (Permian).

## Characteristics of Unayzah Fields

### **Raghib and Dilam Discoveries (1989), Saudi Arabia**

#### **Structure**

- Drape anticlines with 30 to 100m closure

#### **Source Beds**

- Qusaiba Shale, Silurian

#### **Reservoir Beds**

- "A" Member, Unayzah Formation, Permian
- Alluvial and fluvial quartz sandstone
- Carbonate and clay matrix
- Total formation 50 to 300 m thick

#### **Reservoir Properties**

- Porosity generally > 20%
- Permeability up to several darcys

#### **Oil Character**

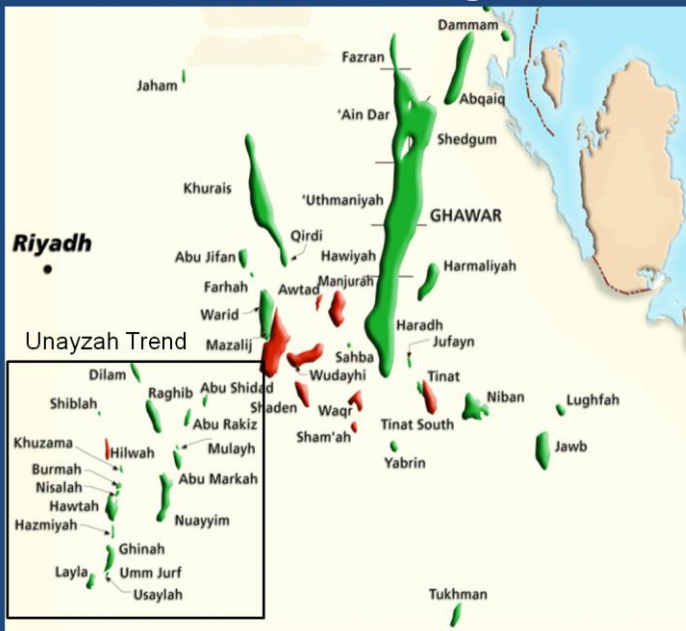
- 44 to 46° API
- Very low sulfur
- Initial production 3000 to 4300 BOPD

From: McGillivray and Hussein (1992)

Presenter's notes: Characteristics of high gravity, low sulfur Unayzah oil, which differs from low gravity, high sulfur Arab D (Jurassic) oil.



# Shaib Thamamah Geologic Model



Source: [http://205.254.135.24/EMEU/cabs/Saudi\\_Arabia/images/Oil%20Gas%20Fields%20Map.gif](http://205.254.135.24/EMEU/cabs/Saudi_Arabia/images/Oil%20Gas%20Fields%20Map.gif)



## Summary

Select fall & winter images when low sun-angle highlights subtle topographic features that may express structures

In arid & semiarid terrane the enhanced color TM images are superior (TM bands 7-4-2 shown in red-green-blue)

A geologic model aids recognition of anomalies

Field checks of anomalies

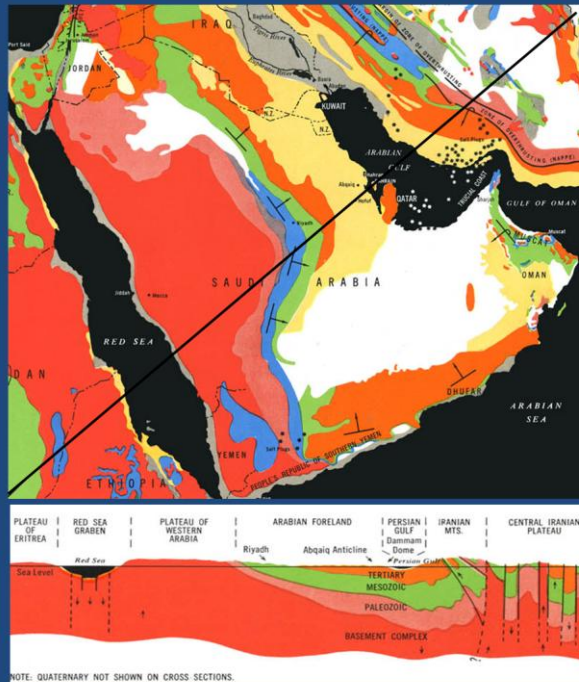
An abstract painting with a complex, layered composition. The background features a mix of deep purples, blues, and earthy yellows and oranges. The texture appears to be built up with various brushstrokes, creating a sense of depth and movement. The overall effect is one of organic complexity and vibrant color contrast.

## Acknowledgements & Thanks to:

Bob Brovey  
Larry Wender  
Jim Ellis  
Saudi Aramco

Presenter's notes: Summary.

# Regional Geologic Map with Northeast-Southwest Cross Section



Source: [http://codex99.com/cartography/images/saudi\\_geology\\_lg.jpg](http://codex99.com/cartography/images/saudi_geology_lg.jpg)



Source: [http://205.254.135.24/EMEU/cabs/Saudi\\_Arabia/images/Oil%20Gas%20Fields%20Map.gif](http://205.254.135.24/EMEU/cabs/Saudi_Arabia/images/Oil%20Gas%20Fields%20Map.gif)

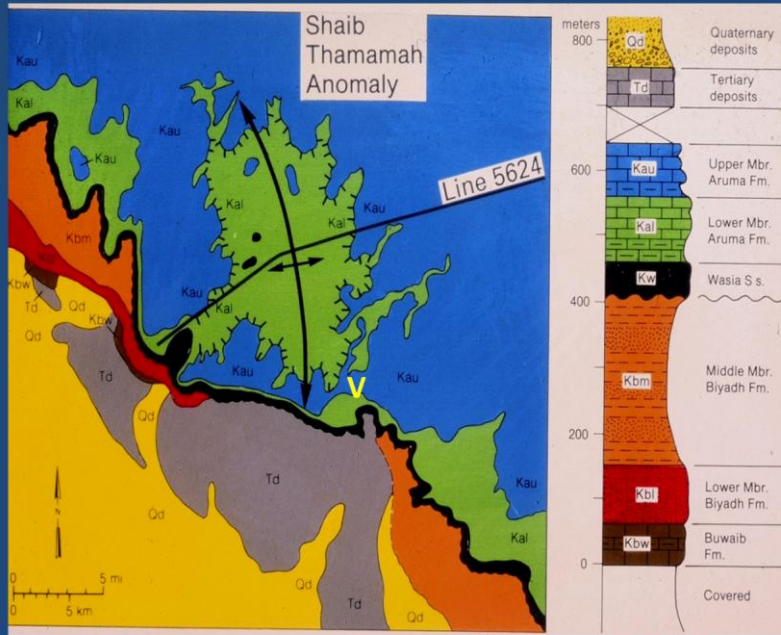


## Unayzah Trend Showing Post-Unayzah Discoveries



Presenter's notes: New oil fields (post-Raghib discovery) in Unayzah Trend. A number of Landsat anomalies are in the trend. However, we lack coordinates of the fields and cannot evaluate any comparisons.

# Geologic Interpretation of Shaib Thamamah Image



Presenter's notes: Geologic interpretation of Shaib Thamamah image. Within the anomaly note outcrops of Wasia Sandstone surrounded by Lower Aruma Member. V – Viewpoint for photos.

## Shaib Thamamah Geologic Model

Underlying Wasia Ss. surrounded by Lower Member of Aruma Fm.



Presenter's notes: Outcrops of Wasia Sandstone surrounded by overlying Lower Member of Aruma Fm within Shaib Thamamah anomaly.

## Dhahran & Dammam Dome

First Saudi oil discovery



Presenter's notes: Landsat thematic mapper image of Dharan and Dammam Dome where Standard Oil of California (Chevron) discovered first oil in Saudi Arabia