

Detection of Hydrocarbon Microseepage Anomalies in the Kirthar Fold and Thrust Belt, Pakistan Through Application of Image Enhancement and GIS Techniques*

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Abstract

This study is based on spectral analysis of rocks exposed in Kirthar Fold and Thrust Belt, Pakistan. It is considered that oil and gas escaping from subsurface reservoirs may interact with surface rocks, soil, and vegetation and produce visible effects that may be interpreted as suggestive of hydrocarbons occurrence. The host rocks may be altered due to chemical and biological interaction with the seeping hydrocarbons. Such rocks have specific spectral responses in various bands of electromagnetic spectrum of light and thus give rise to a number of anomalies, which may be used as suggestive of hydrocarbon presence. The study identifies areas of spectral anomalies (sweet spots) which are considered to be related to the possible presence of working petroleum system in the Kirthar Fold and Thrust Belt, Pakistan. This objective is achieved through application of Advanced Remote Sensing and GIS techniques and geological understanding of the region.

Reference

Bannert, D., A. Cheema, A. Ahmed, and U. Schaffer, 1992, The structural development of the western fold belt, Pakistan: *Geologisches Jahrbuch Reihe B.*, v. 80, 60 p.

Detection Of Hydrocarbon Microseepage Anomalies In The Kirthar Fold & Thrust Belt, Pakistan Through Application Of Image Enhancement And GIS Techniques

Noushaba Hisam

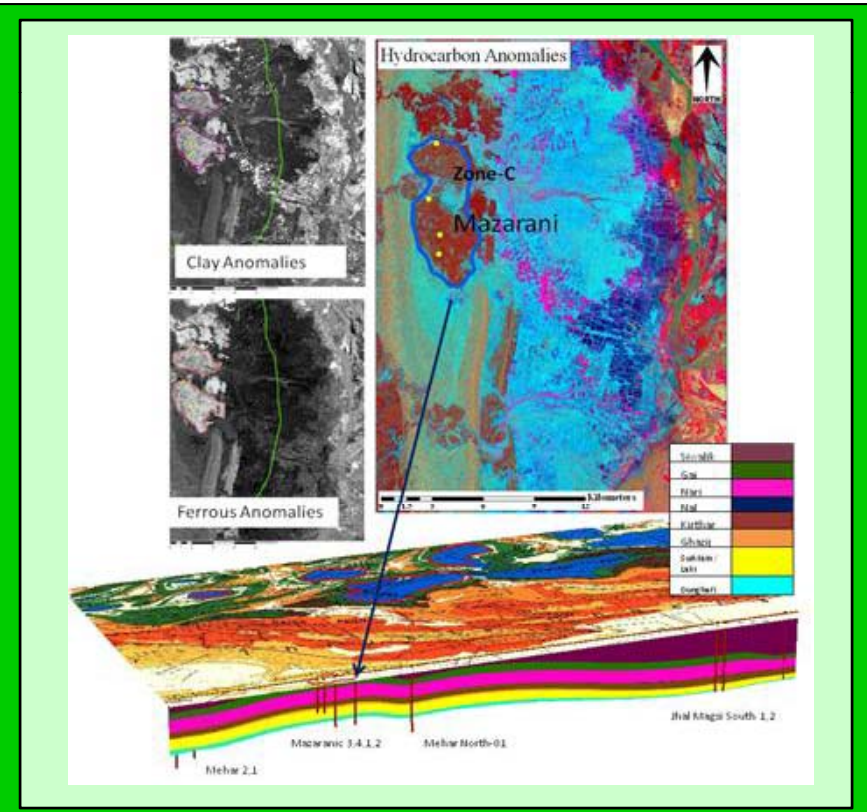
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Contents

10-11 November, 2010

Slide 2

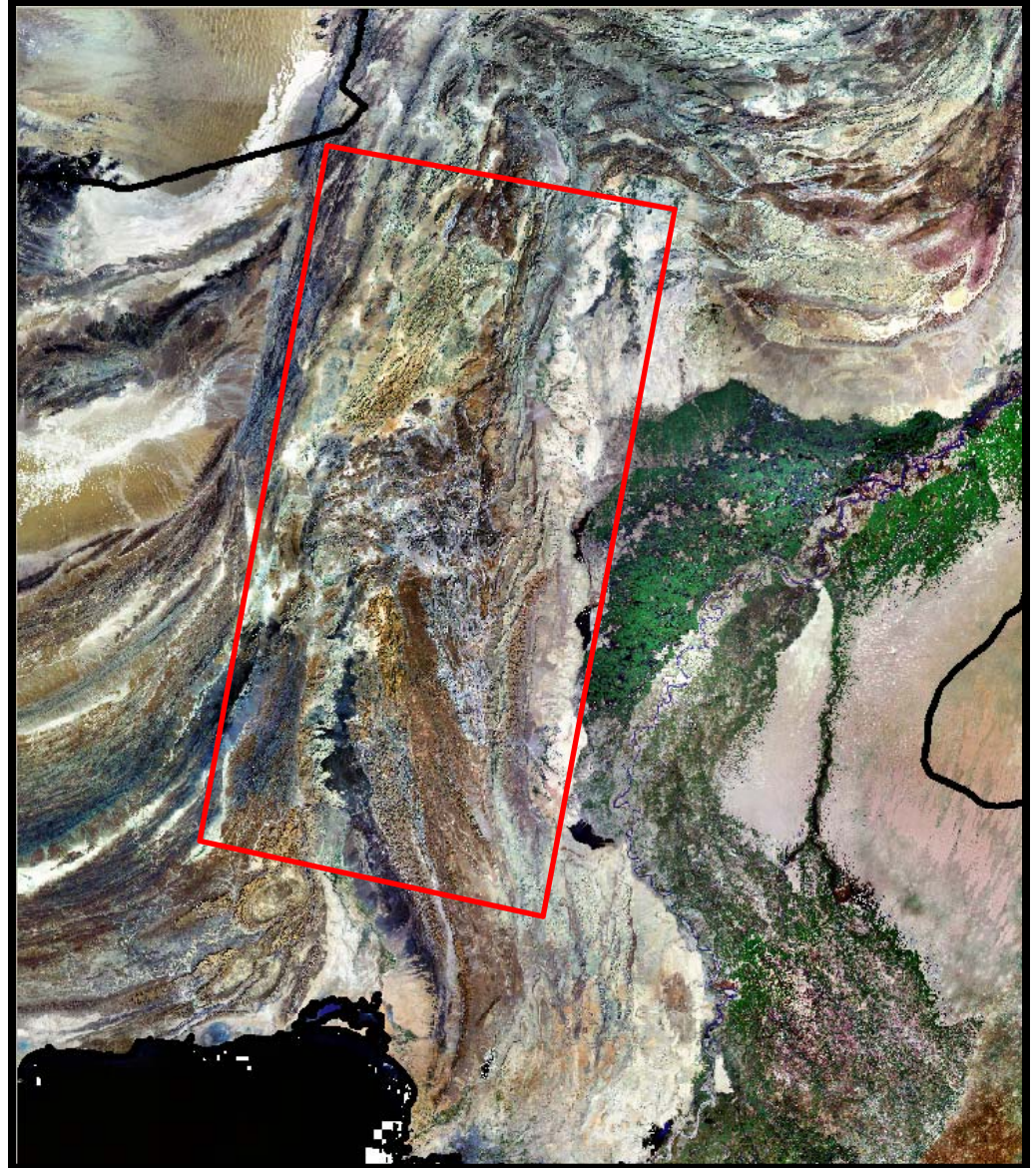
- Objectives
- Concept
- Database/Software
- Geology Of The Area
- Petroleum System
- Image Enhancement Techniques
- Identification Of Spectral Anomalies On Image
- Conclusion

Objective

10-11 November, 2010

Slide 3

- ❑ To identify areas having spectral anomalies (sweet spots) in Kirthar Foldbelt, Pakistan
- ❑ Application of Remote Sensing / GIS techniques and geological understanding of the region for detection of spectral anomalies which are considered to be related to HC occurrence





Concept

10-11 November, 2010

Slide 4

- Areas where hydrocarbons are escaping to the surface, a reducing-acidic environment occurs which leads to alteration of rocks
- Clays are altered from Montmorillonite to Kaolinite (higher Kaolinite and lower Montmorillonite) and Ferric iron (Fe^{+3}) to Ferrous iron (Fe^{+2}) with a specific anomalous response on enhanced images
- The target minerals for hydrocarbon indication are thus iron (as Hematite), Kaolinite, and Montmorillonite
- Through application of Remote Sensing and GIS such concentration (anomalies) are imaged and thematic maps are prepared

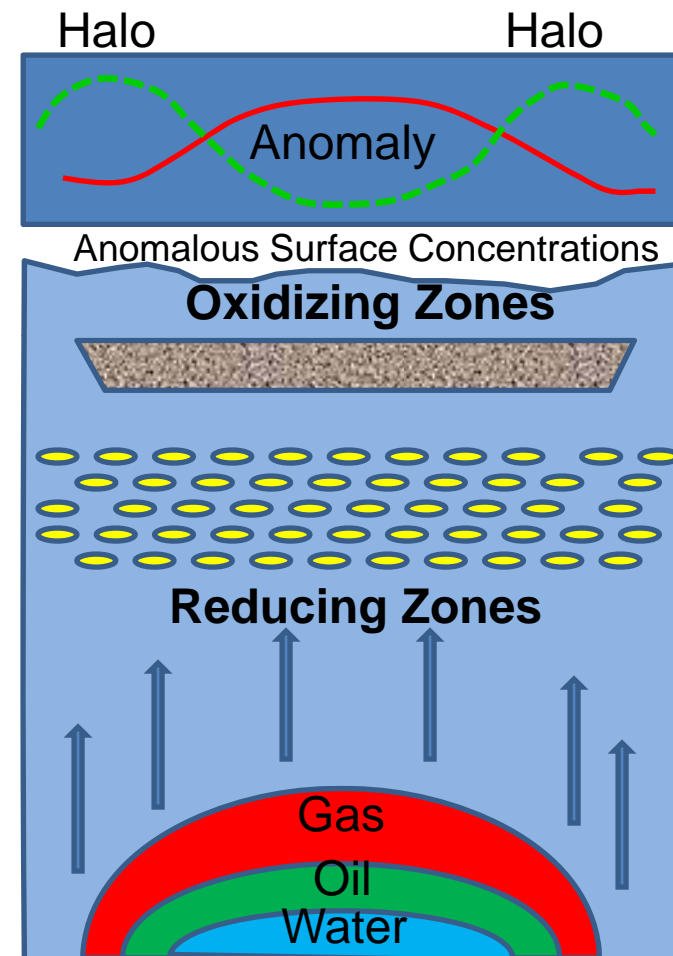
Microseepage Model

10-11 November, 2010

Slide 5

Hydrocarbon seepage may show:

- Bleaching of Hematite, and
- Enrichment in Kaolinite relative to Montmorillonite



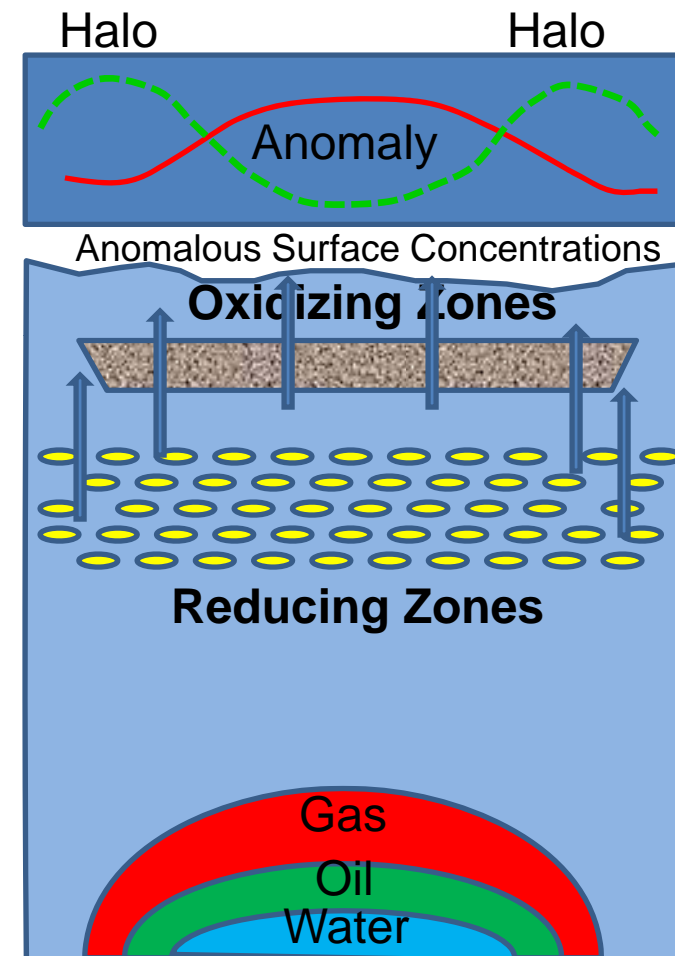
Microseepage Model

10-11 November, 2010

Slide 6

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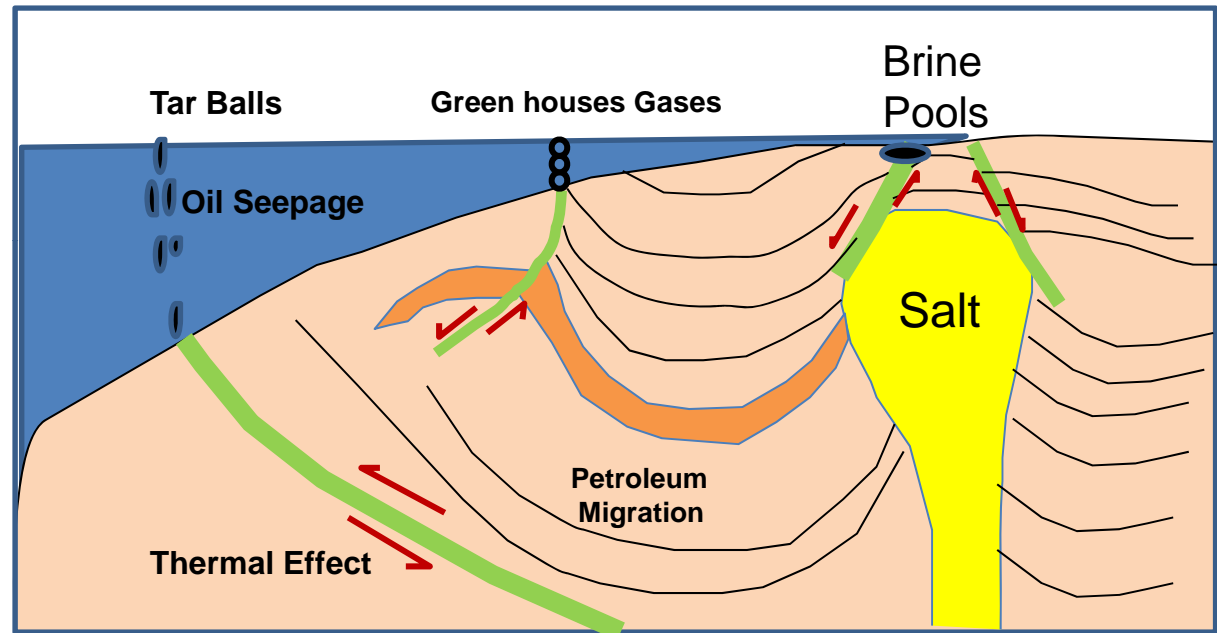


Microseepage Model.....2

10-11 November, 2010

Slide 7

- Generally oil and gas migrate to the surface through nearly vertical pathways as a result of reservoir/seal leakage

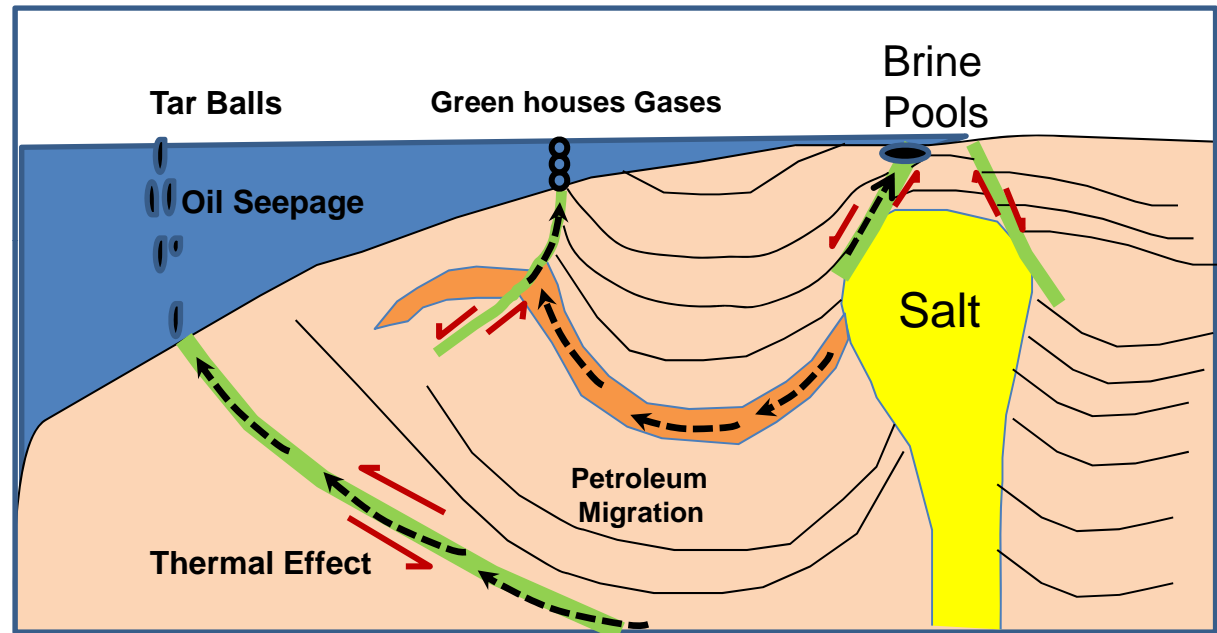


Microseepage Model.....2

10-11 November, 2010

Slide 8

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Database /Software

10-11 November, 2010

Slide 9

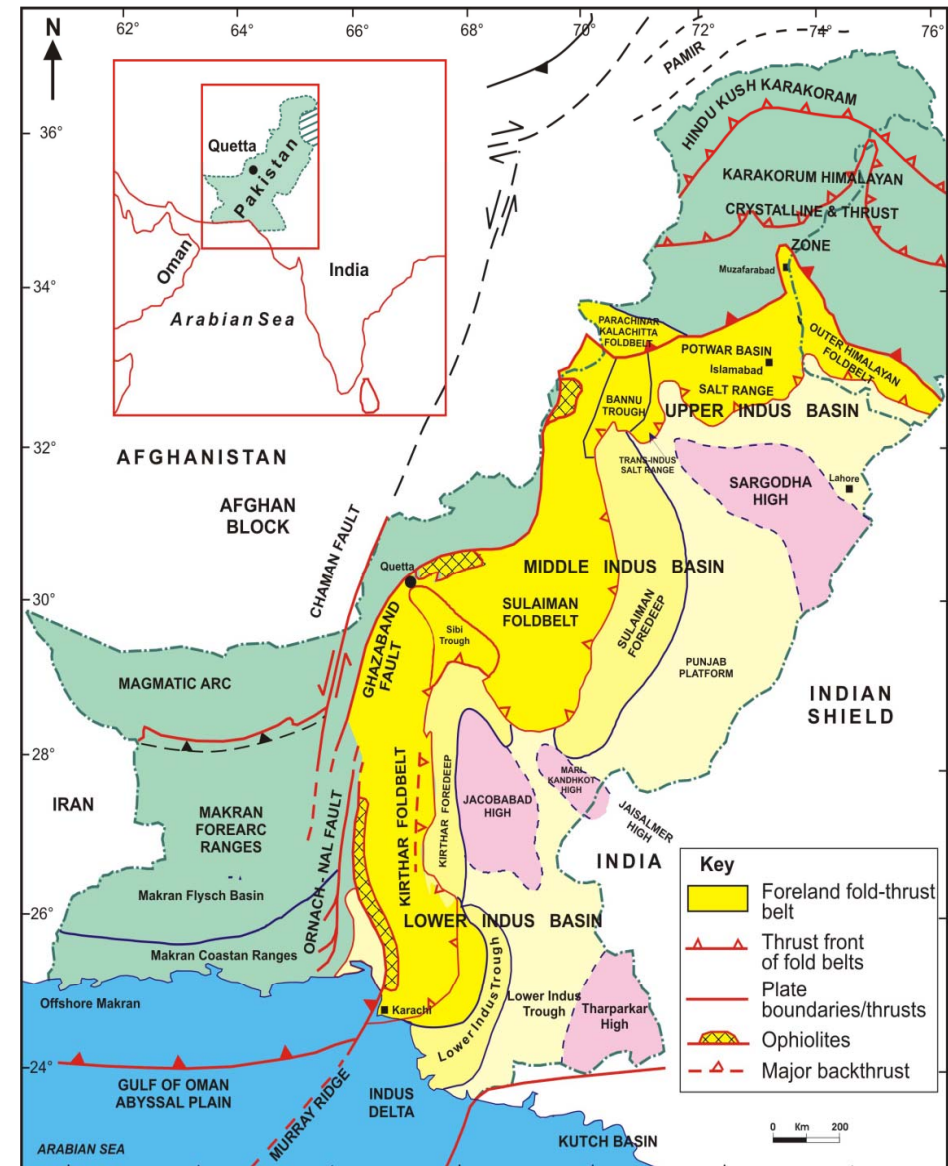
- Geological Reports and Published literature
- Bannert et al, 1992 Maps derived from MSS Satellite Imagery
- A Landsat ETM+ scene (path 153, rows 40 and 41) with the Spatial Resolution of 30 m, comprising 8 Spectral Bands
- Satellite image
- ERDAS Imagine
- ArcGIS

Tectonic Elements

10-11 November, 2010

Slide 10

- ❑ Major tectonic elements in Pakistan are result of collision between Indian & Eurasian plates during Miocene / Pliocene, which started earlier during Late Cretaceous/Paleocene.
- ❑ Oil & Gas bearing structures in the AOI are result of this compression
- ❑ The study area is dissected by longitudinal faults
- ❑ Kalat Fault bounds Kalat Plateau in the west
- ❑ Fold axes are trending north-south in Kalat Fold Belt and Kalat Plateau
- ❑ In Khuzdar area fold axes are generally NNW-SSE trending

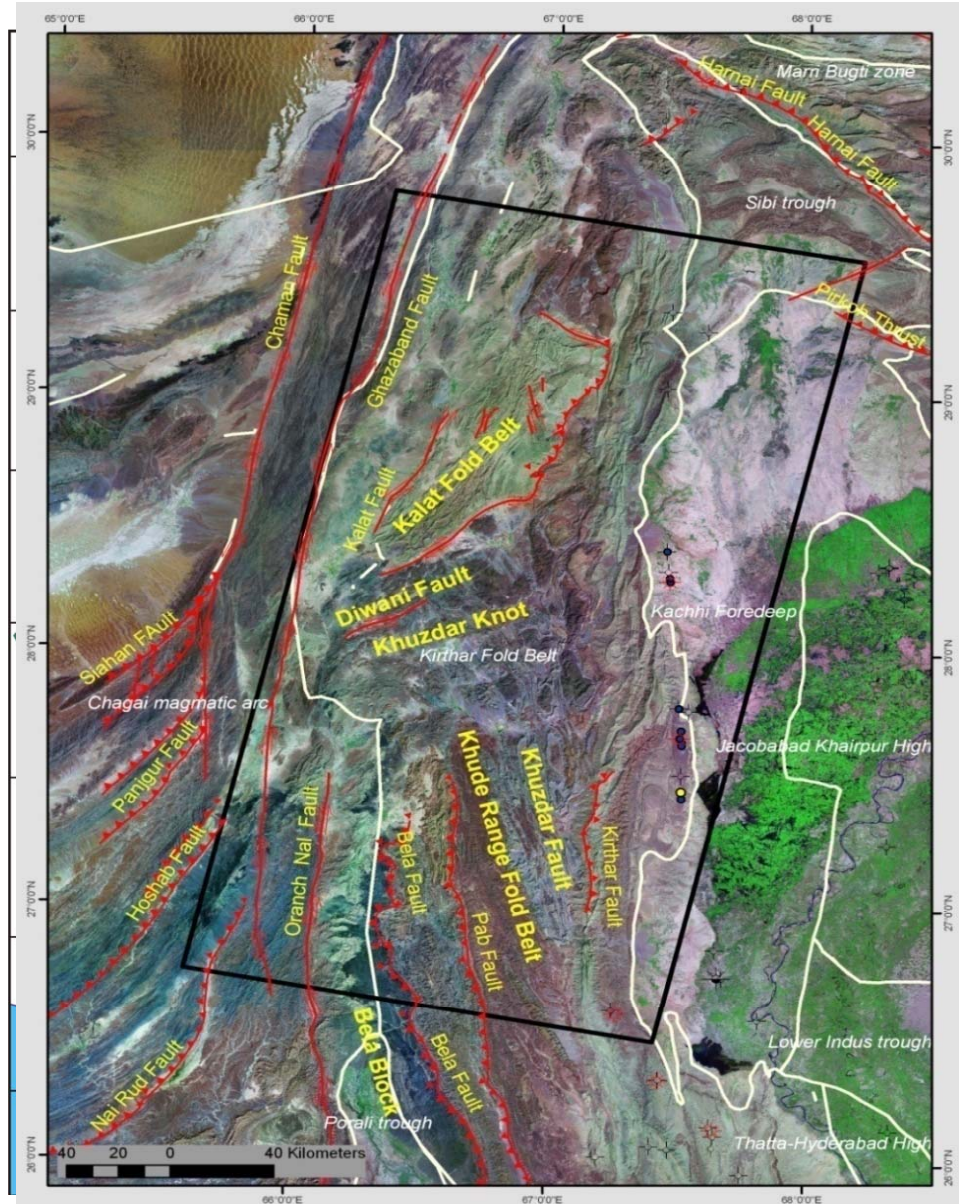


Tectonic Elements

10-11 November, 2010

Slide 11

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Stratigraphy – Petroleum System

Proven Reservoirs of the area:

- ❑ Pab Fm. producing in Mehar-01
- ❑ Ranikot/Dunghan Fm. producing in Mehar-02 and Jhal Magsi South-01
- ❑ SML /Laki producing in Mazarani and Jhal Magsi fields

SYSTEM	AGE		FORMATION	LITHOLOGY	PETROLEUM SYSTEM		
	PERIOD	PERIOD			SOURCE	RESERVOIR	SEAL
Quaternary	PLEISTOCENE	RECENT	ALLUVIUM				
		OLOCENE	CHATTIAN	NARI / GAJ			
Eocene	MIDDLE		RUPELIAN				
		BARTONIAN	KIRTHAR				
Eocene	EARLY	LUTETIAN					
		YPRESIAN	GHAZIJI				
Eocene	EARLY	YPRESIAN	SML / LAKI				
		THANETIAN	DUNGHAN/RANIKOT				
Eocene	PALEOCENE	MONTIAN					
		DANIAN	KHADRO				
Cretaceous	LATE	MAASTRICHTIAN	PAB				
		CAMPANIAN	MUGHALKOT				
Cretaceous	EARLY	SANTONIAN					
		CONIACIAN	PARH				
Cretaceous	EARLY	TURONIAN					
		CENOMANIAN	GORU				
Cretaceous	EARLY	ALBIAN					
		APTIAN					
Cretaceous	EARLY	BARREMIAN	SEMBAR				
		HALTERMIAN					
Cretaceous	EARLY	VALANGINIAN					
		BERRASIAN	CHILTAN				
Cretaceous	EARLY	BATHONIAN					
		BAJOCIAN	ANJIRA				
Cretaceous	EARLY	AALENIAN	LORALAI				
		TOARCIAN	SPINGWAR				
Cretaceous	EARLY	STENMURIAN					
		TETHYAN					
Mesozoic	JURASSIC	WULGAI (Alozai)					
		Zaluch Group					
Paleozoic	PERMIAN	Nilawahan Group					
		BAGHANWALA					
Paleozoic	CAMBRIAN	JUTANA					
		KUSSAK					
Paleozoic	CAMBRIAN	KHEWRA					
		SALT RANGE FORMATION					
Pre-Cambrian	INTRA-CAMBRIAN	BASEMENT					

Geological Setting

10-11 November, 2010

Slide 13

- ❑ Outcrops from Jurassic up to Oligocene age cover the AOI
- ❑ Kalat Fold Belt is covered by Jurassic rocks and Kalat Plateau by Eocene Kirthar limestone
- ❑ Khuzdar area contain series of Jurassic cored anticlines
- ❑ South of Khuzdar Knot, Cretaceous through Oligocene rocks present

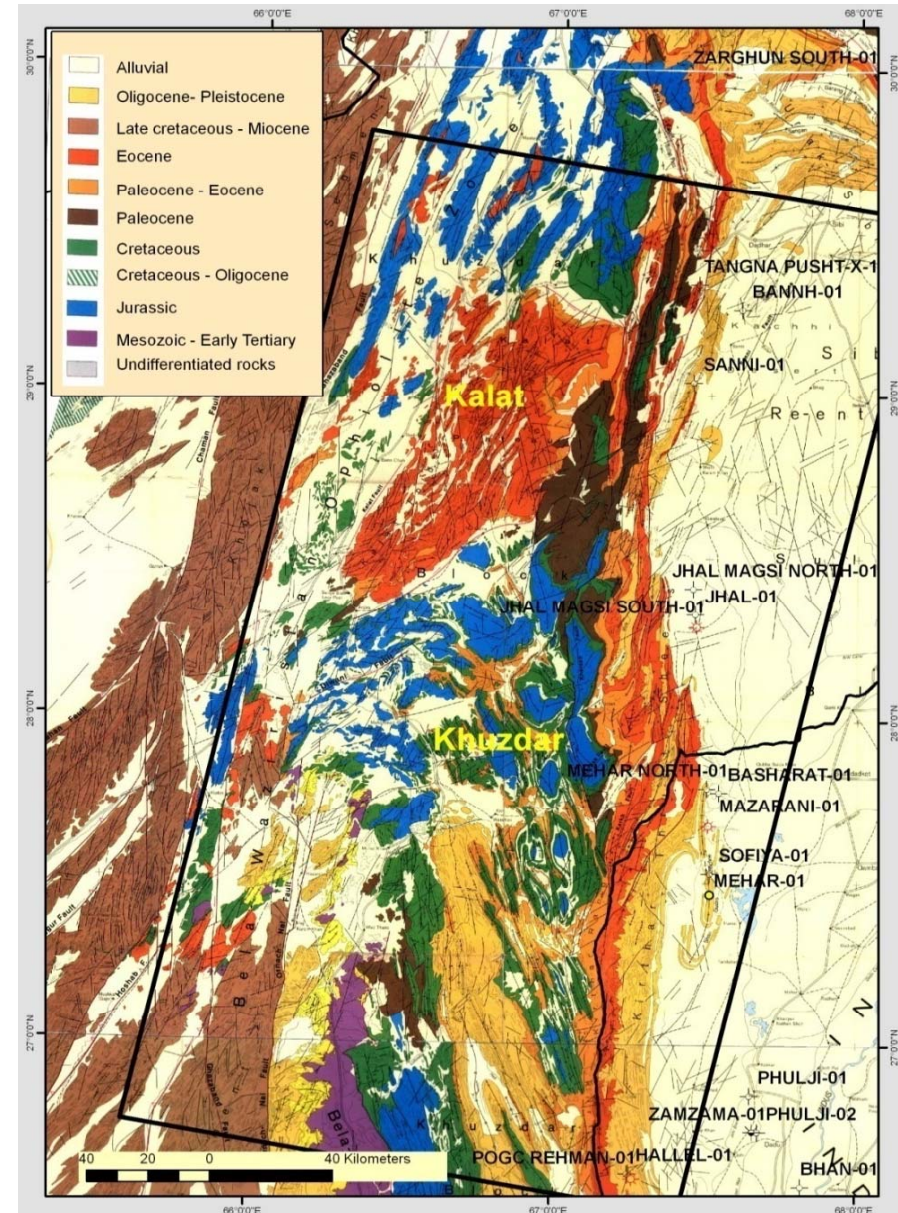


Image Enhancement Techniques

10-11 November, 2010

Slide 14

Three image enhancement techniques, including

- ❑ **Principal component analysis (PCA)** is used to compress the information content of a number of bands of imagery into fewer bands transformed Principal Component images
- ❑ **Band rationing** is helpful to acquire unique information about certain features. For example, the Normalized Difference Vegetation Index (NDVI) is specifically used to identify vegetation.
- ❑ **False-color composition (FCC)** is used to visualize the anomalous areas.



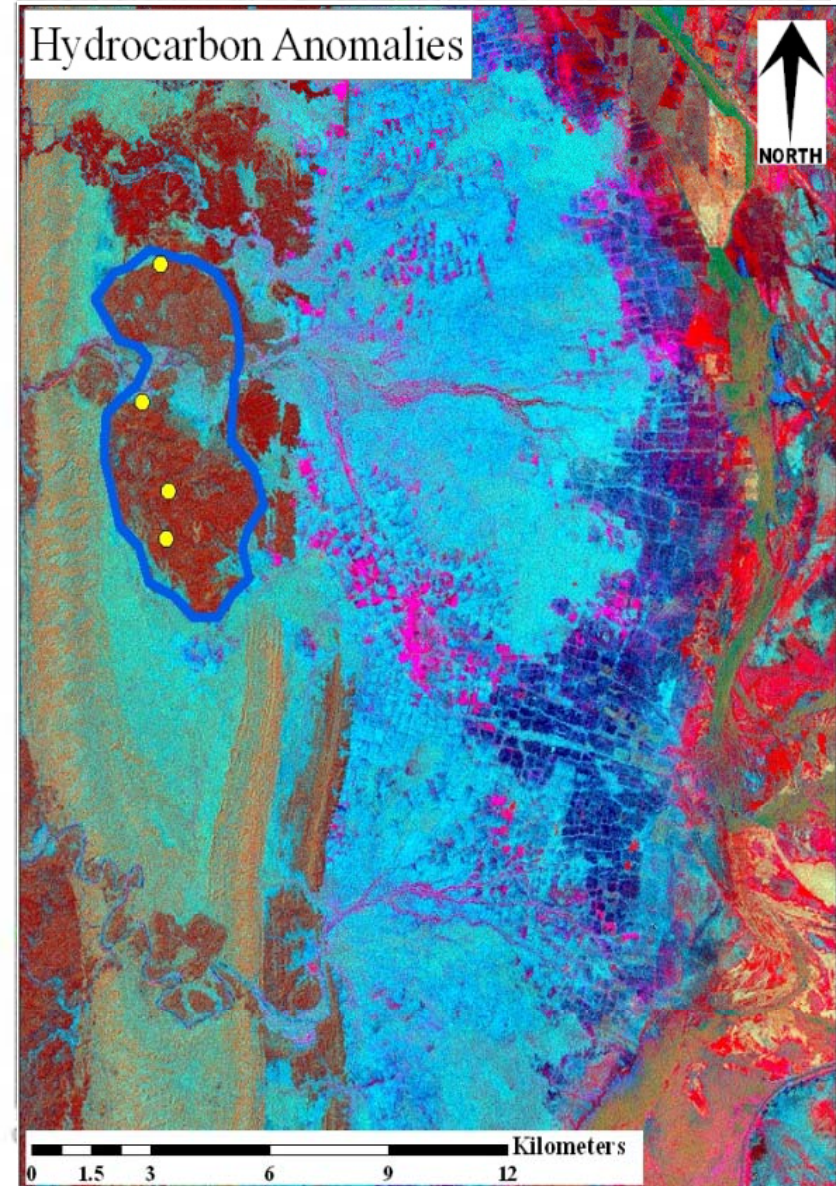
Image Enhancement Techniques

10-11 November, 2010

Slide 15

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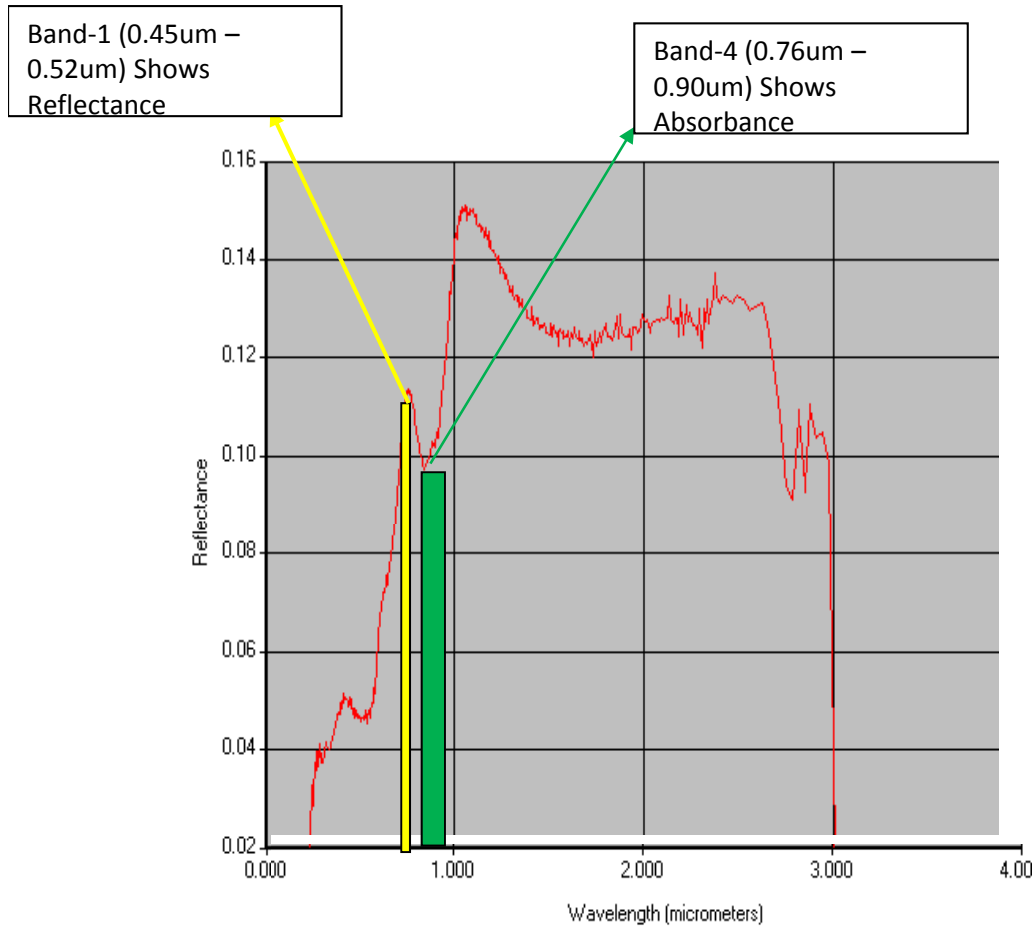
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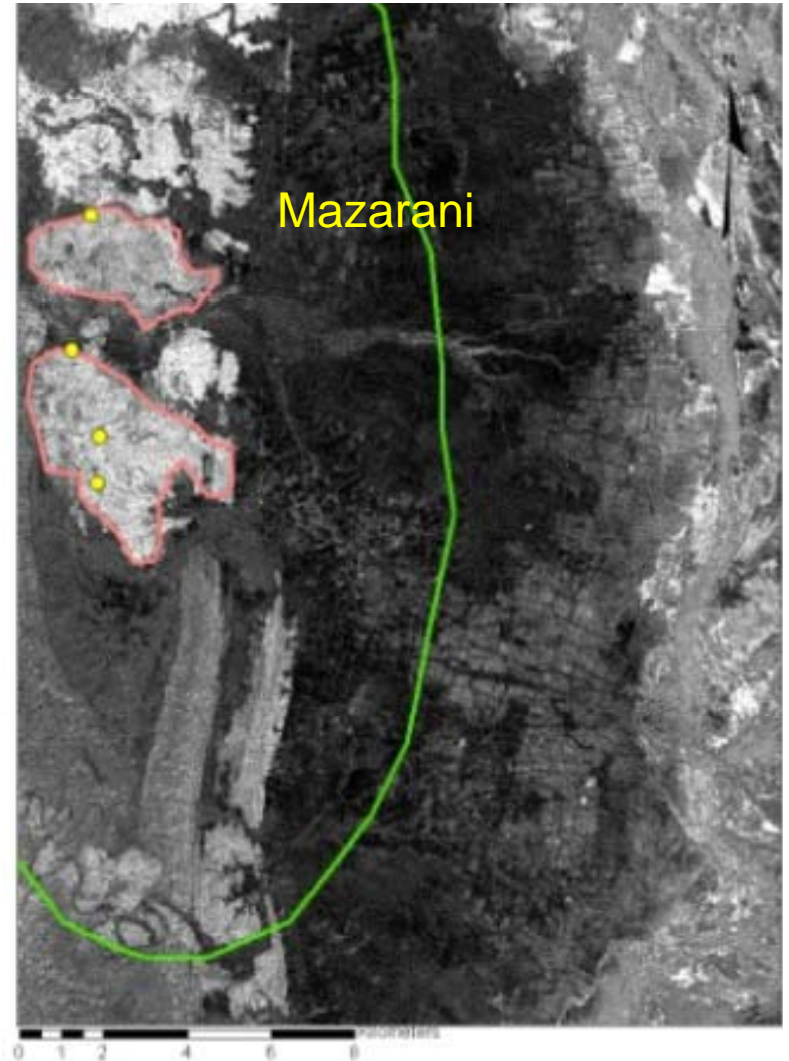
Hematite Signature (Erdas Library)

10-11 November, 2010

Slide 16



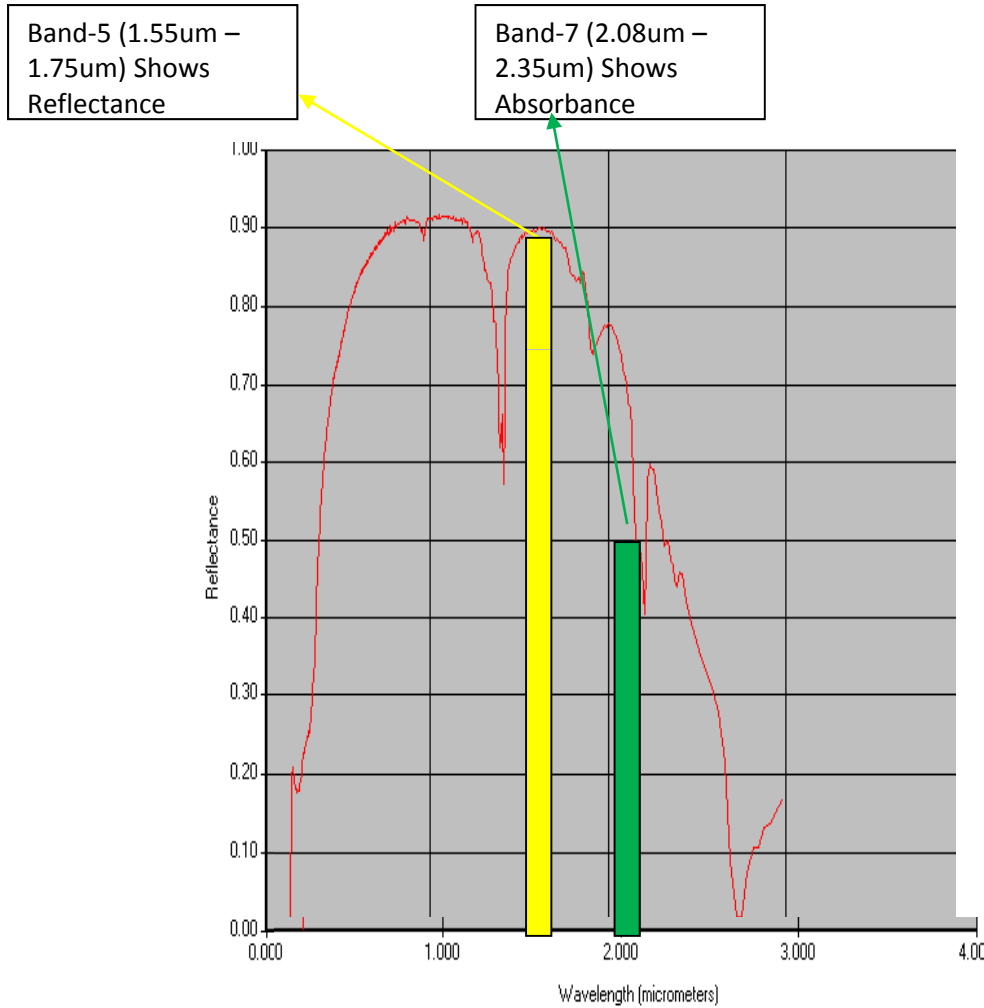
Hematite Anomalies



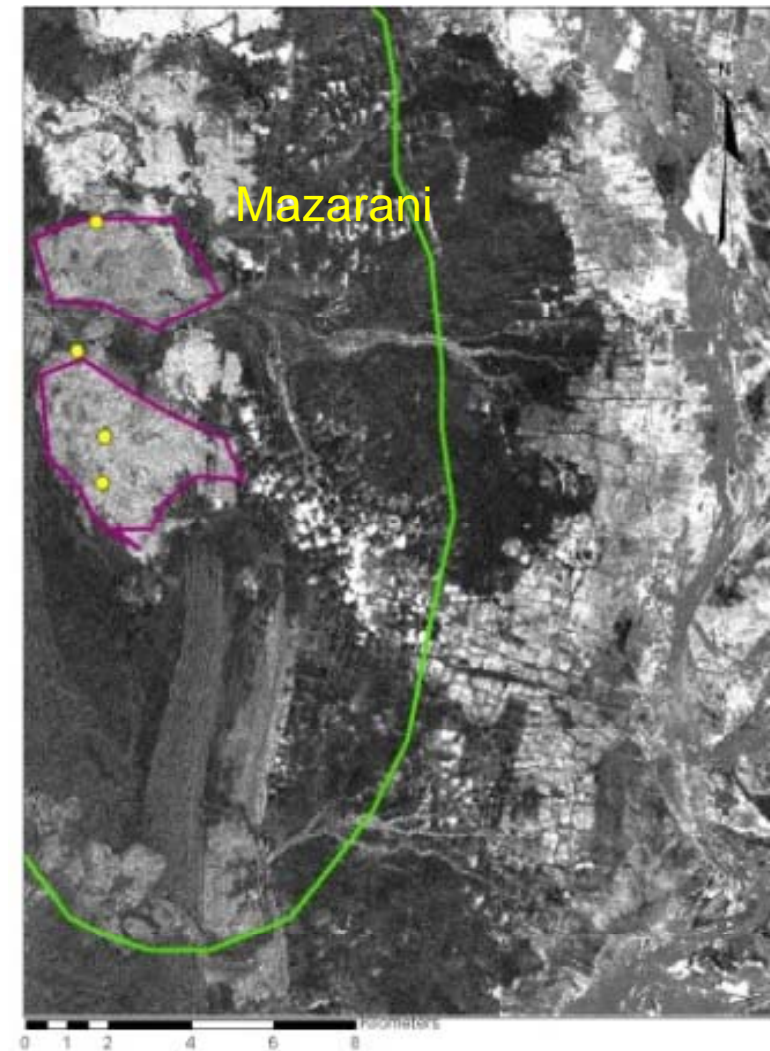
Kaolinite Signature (Erdas Library)

10-11 November, 2010

Slide 17



Clay Anomalies

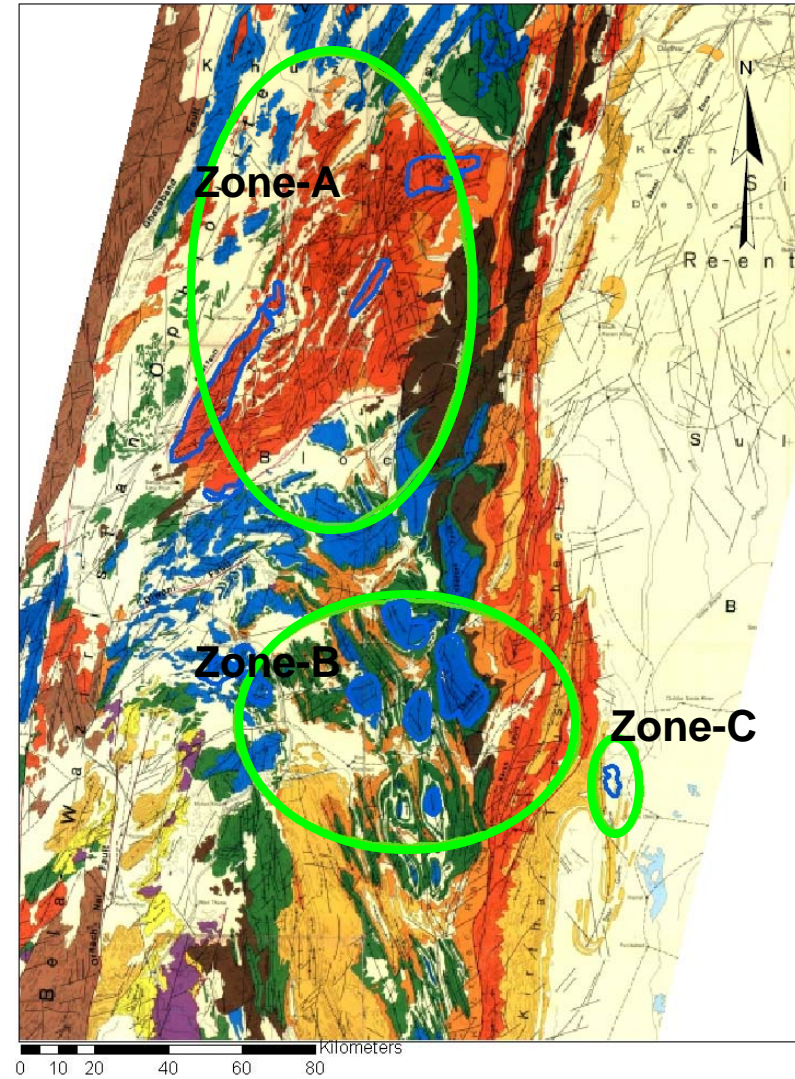


Identification Of Spectral Anomalies On Image

10-11 November, 2010

Slide 18

- ❑ On the basis of anomalies the study area is divided into A, B and C zones
- ❑ Zone-A indicates the northern part of Kirthar Range i.e. Kalat region, Zone B is the area around Khuzdar and Zone-C is Mazarani field area
- ❑ These zones are highly deformed by fractures and faults. These faults might have facilitated hydrocarbon seep with a higher likelihood of rock alteration due to hydrocarbon induced spectral anomalies

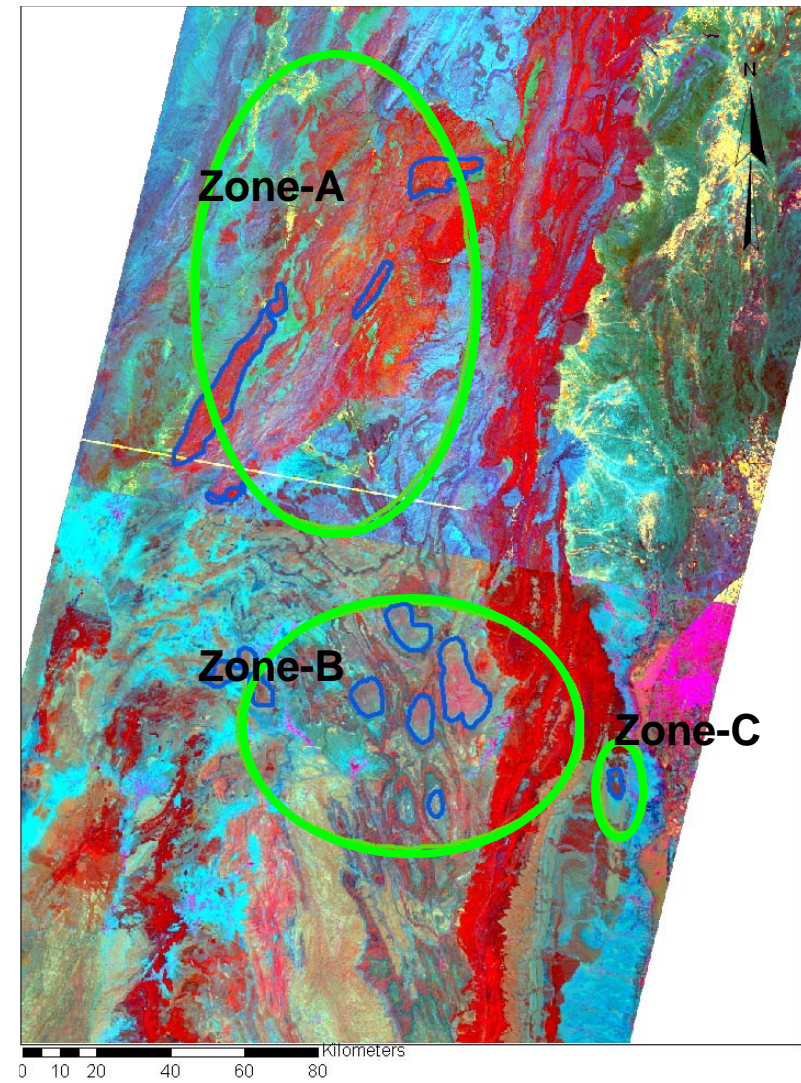


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10-11 November, 2010

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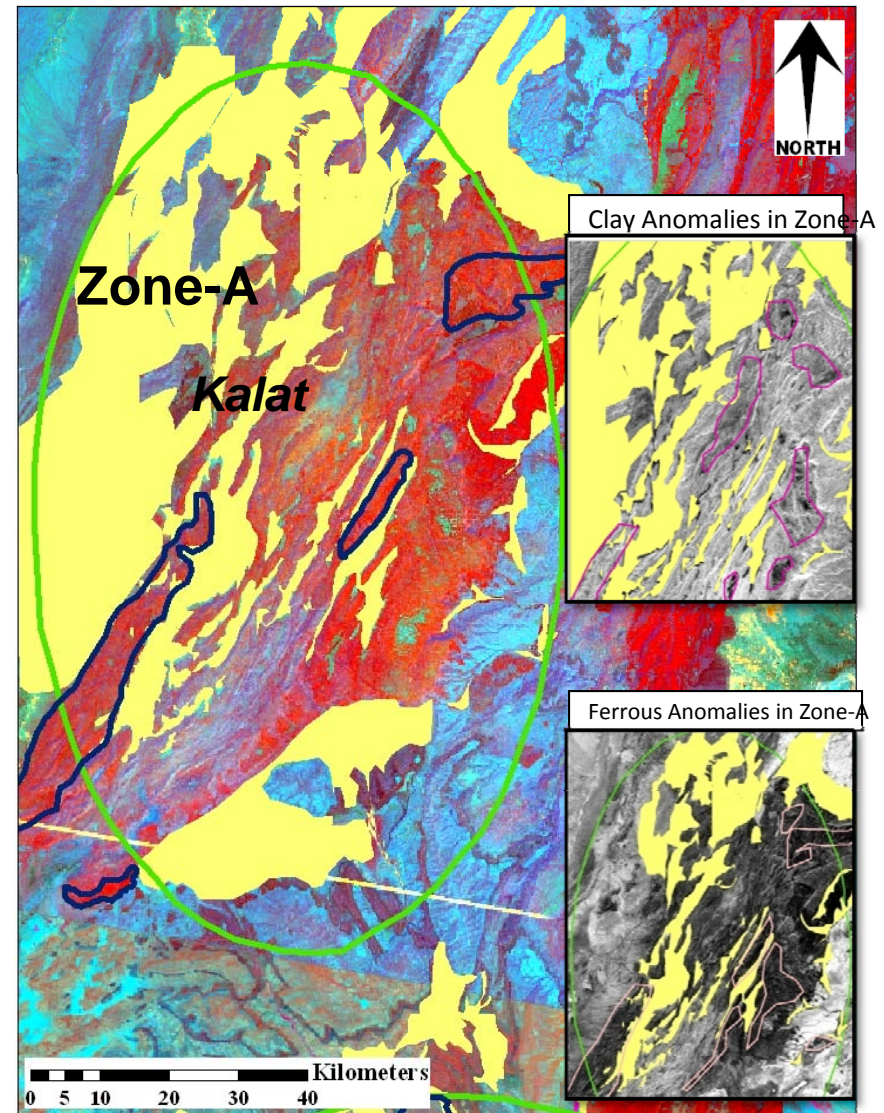


Identification Of Spectral Anomalies On Image

10-11 November, 2010

Slide 20

- In Zone-A, weak anomalies are present in the Eocene rocks, which give poor response on enhanced images.
- Its reason may be possibly due to weak hydrocarbon seep which may in turn be associated with relatively deeper reservoir or micro-seep has been exhausted
- Thus, Zone-A is relatively poor in altered clay minerals

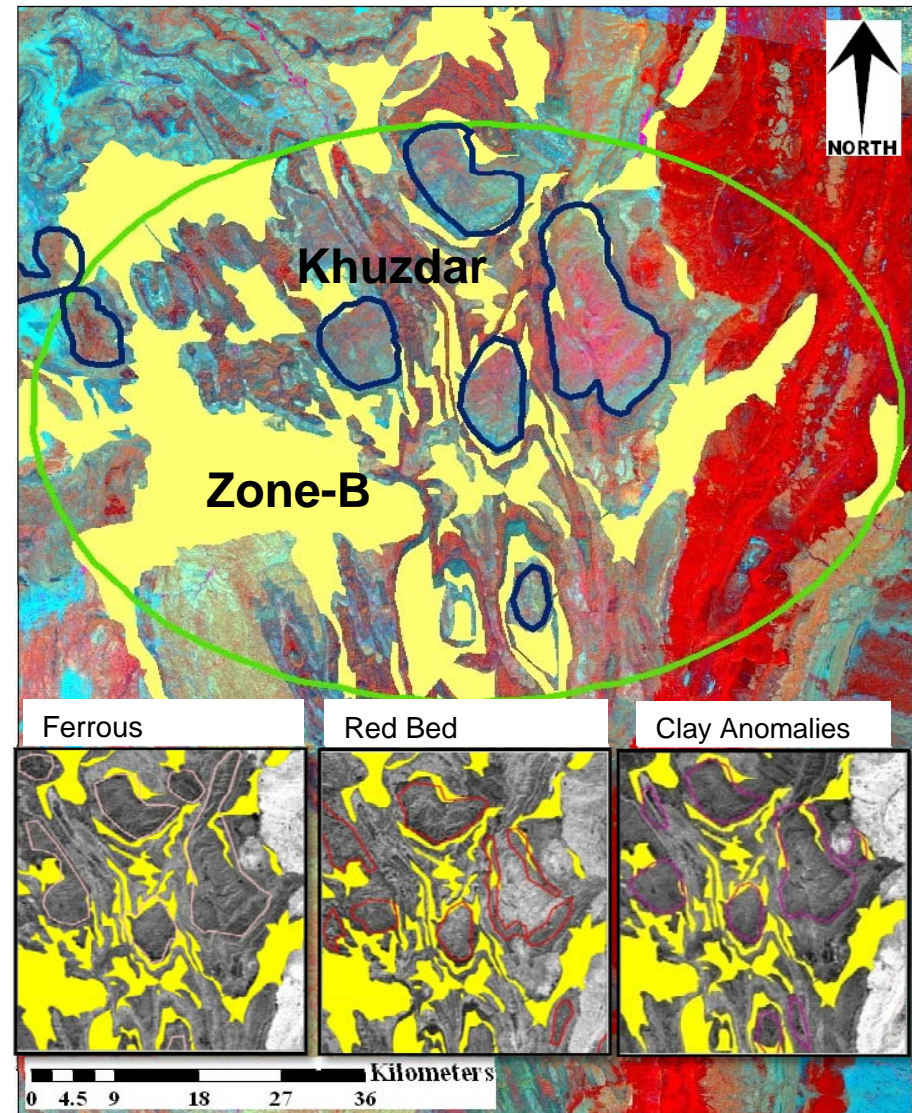


Identification Of Spectral Anomalies On Image

10-11 November, 2010

Slide 21

- ❑ Zone-B is dominated by more anomalies
- ❑ On enhanced images these anomalies were observed in Cretaceous and Jurassic outcrops
- ❑ This zone is relatively rich in altered Kaolinite and Ferrous thus shows more hydrocarbon related anomalies

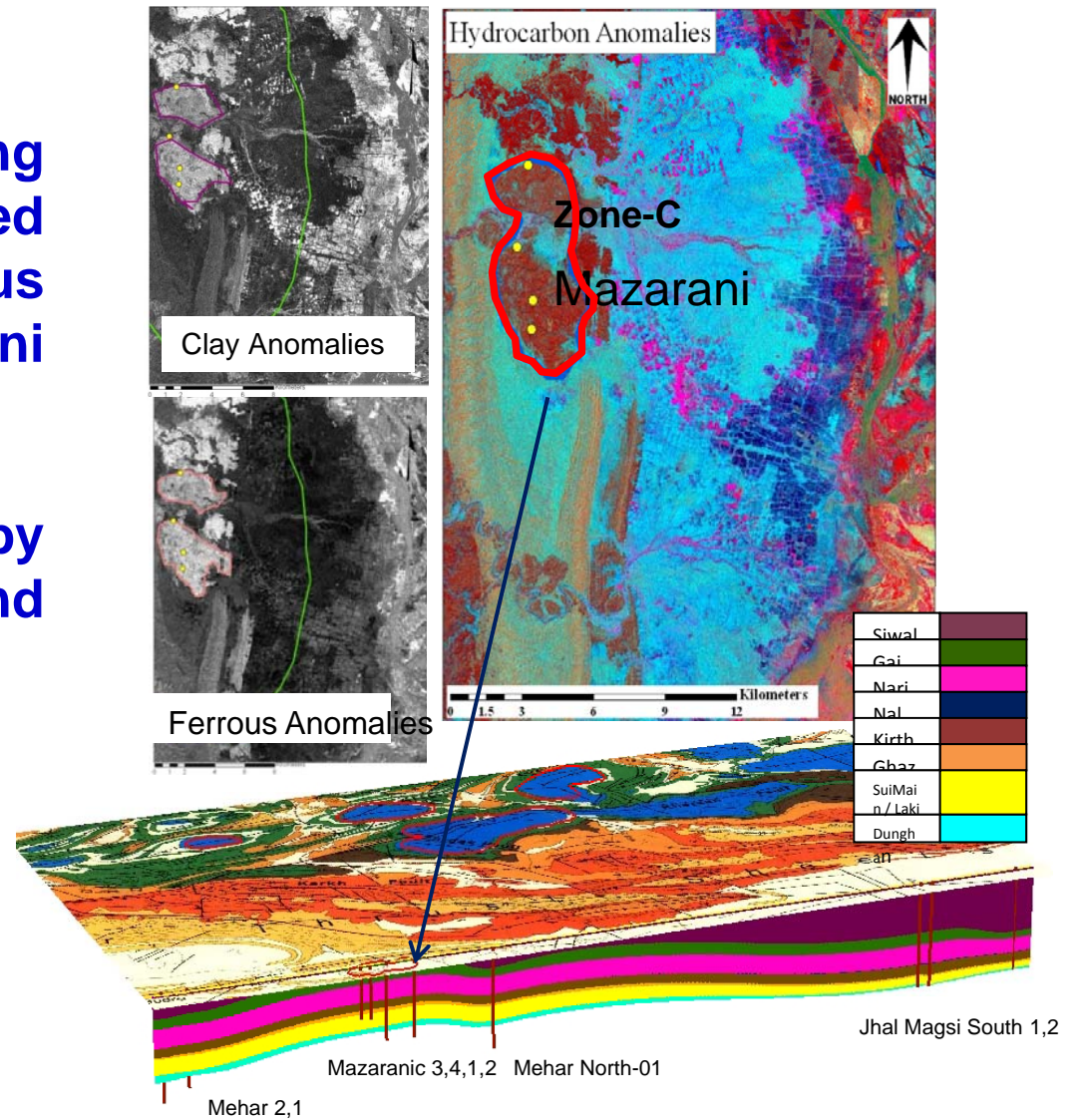


Identification Of Spectral Anomalies On Image

10-11 November, 2010

Slide 22

- In Zone-C, strong anomalies of altered Kaolinite and Ferrous occurs around Mazarani area
- The area is covered by thin cover of Siwalik and alluvium





Conclusion

10-11 November, 2010

Slide 23

- On the basis of interpretation of satellite data and GIS Techniques it is inferred that the AOI is characterized by a number of spectral anomalies
- These anomalies are possibly associated with hydrocarbon occurrence
- These spectral anomalies need to be substantiated through integration of geological fieldwork and data from geophysical and geochemical sources
- The application of Remote Sensing Techniques will be helpful in understanding the hydrocarbon occurrences in the area
- These techniques, therefore, can be used as reconnaissance tool for hydrocarbon exploration

Thank You..