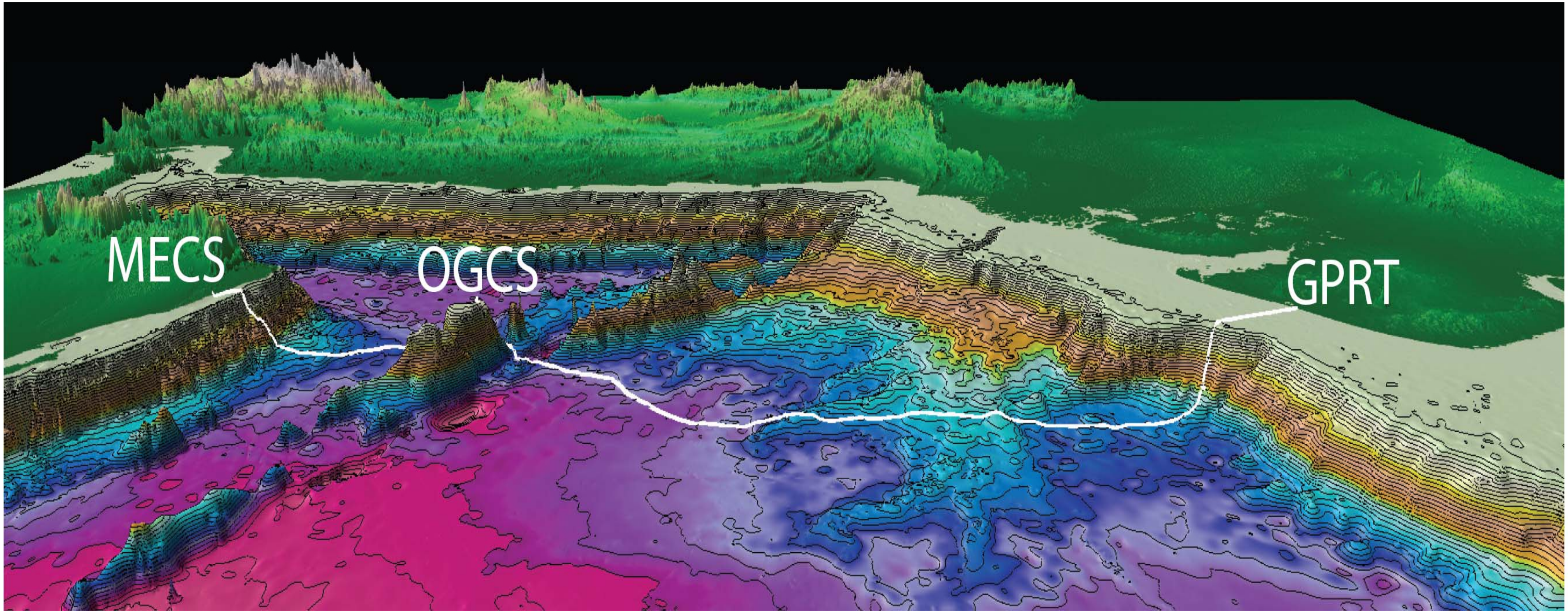
Case study: Middle East to India Deepwater Pipeline (MEIDP) requirements for Installation, Intervention and Emergency Repair



Ian Nash

Project Overview

This case study will look at the details of the Middle East to India Deepwater Pipeline (MEIDP) that is proposed to reach 3450m water depth in its 1300km long route between Oman and India.

Specifically the following will be considered:

- Pipeline Route and geohazard features
- Installation requirements and candidate vessels
- Intervention requirements and candidate vessels
- Emergency pipeline repair systems

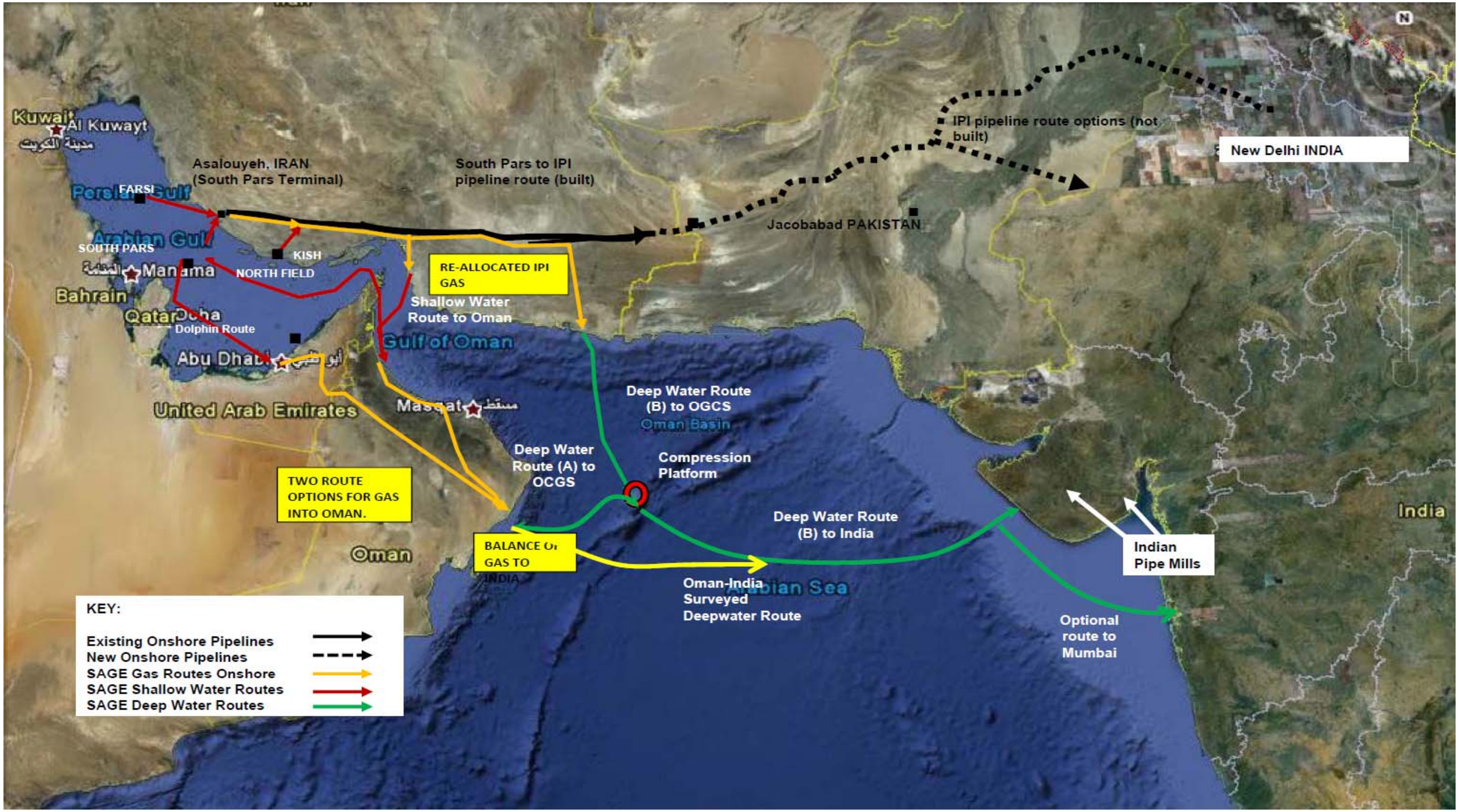
what is currently available in the marketplace?

where gaps exist?

What future plans are there?

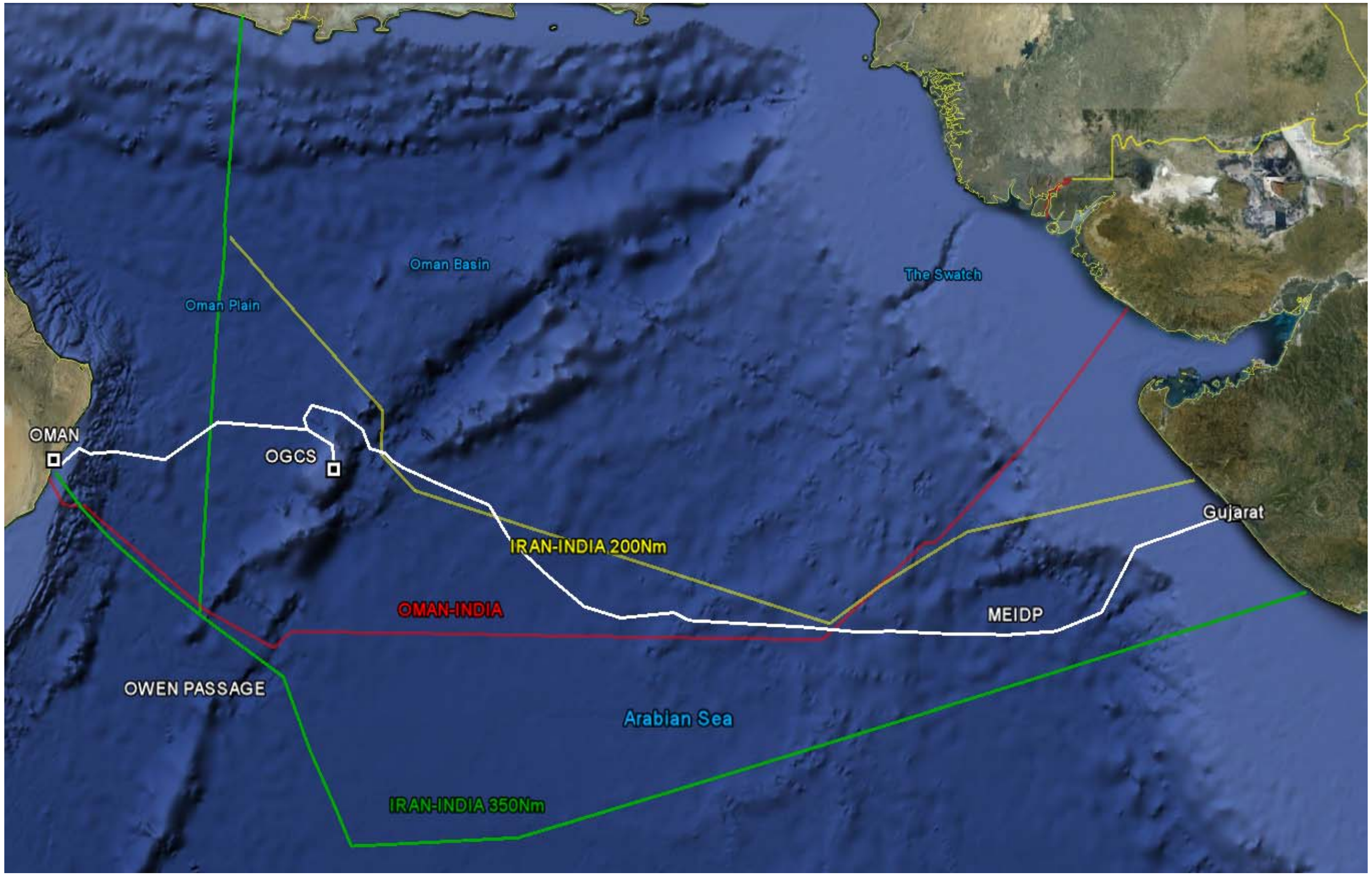
Pipeline Route

MEIDP Project Overview



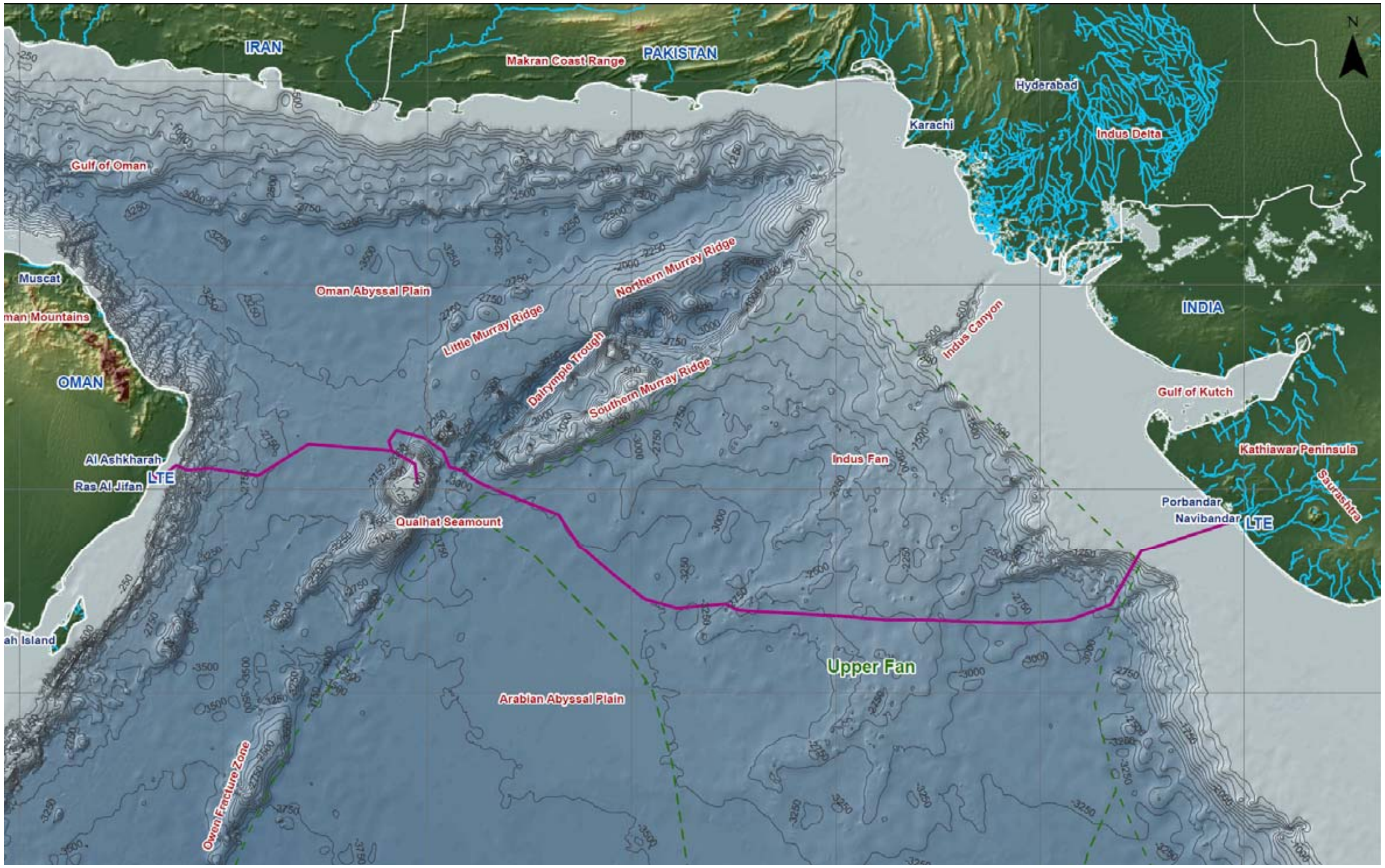
Historical Route Options

- Historically many routes have been considered
  - Oman-India 1995
  - Iran-India 1997
  - Iran-India (200NM) 2003
  - Iran-India (350NM) 2003
  - MEIDP 2010
- All were considered to be Installable.

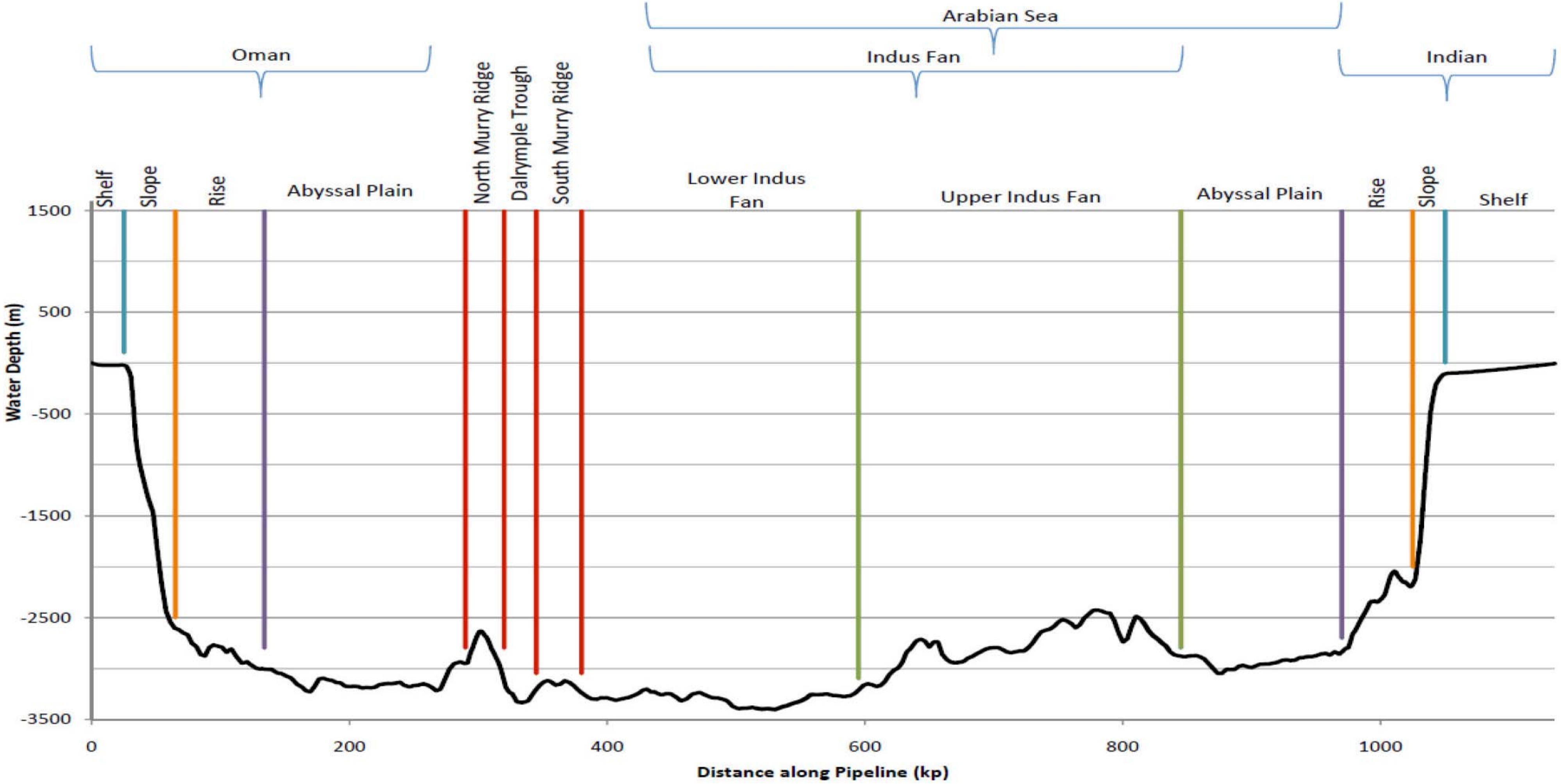


Pipeline Routing

- Routing from Central Oman East coast near Ras AL Jifan and Ghudayran
- Crossing Oman Continental Shelf/Slope/Rise due west
- Crossing Central Oman Abyssal Plain
- Passing North of the Qualhat Seamount
- Crossing the



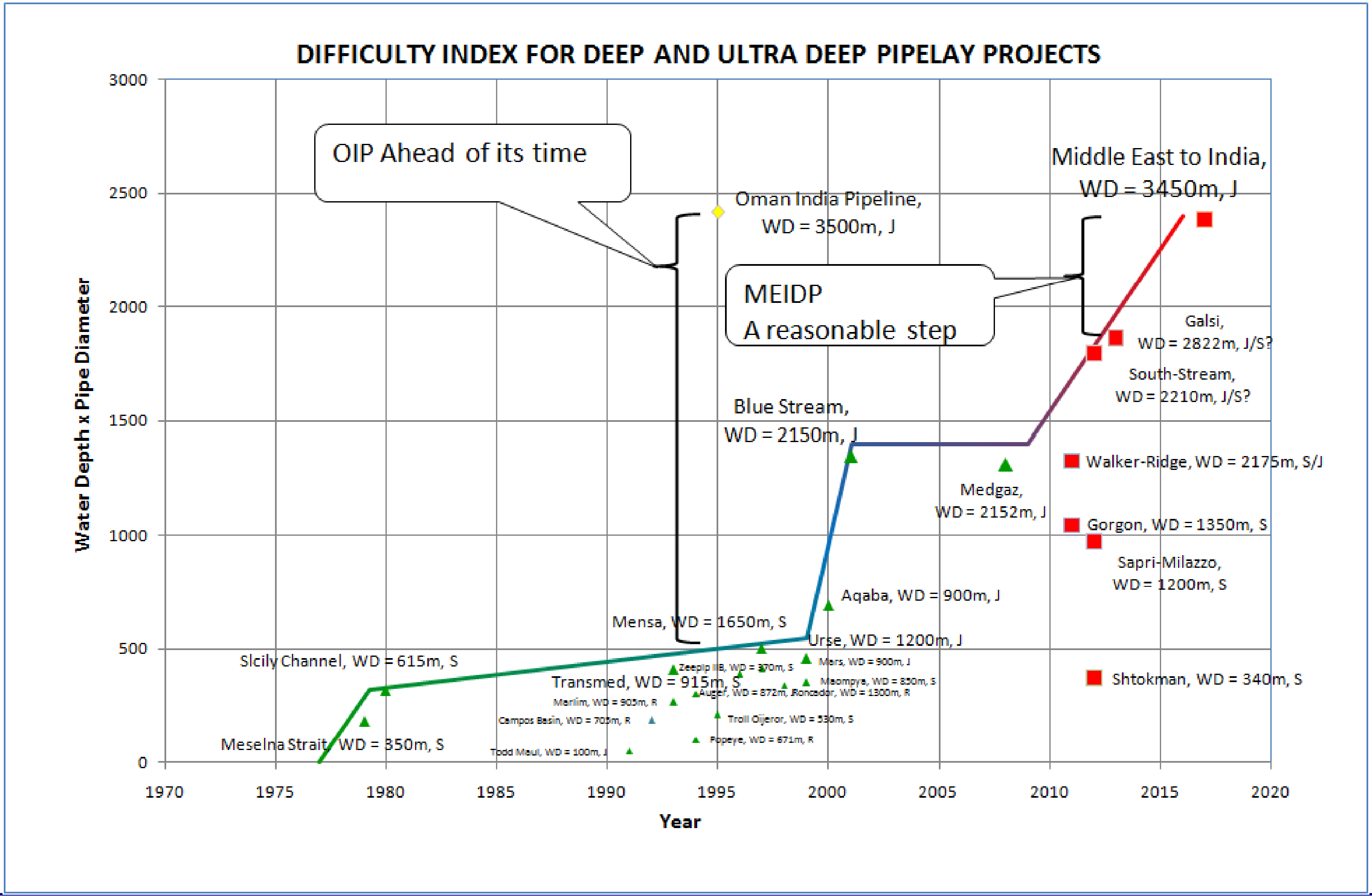
Pipeline route Profile (direct)



Installation requirements

And Vessels

Difficulty Index for Deep Pipelay Projects



Existing Pipelay Vessels in Operation

Saipem S7000 (operational since ####)

Carrying capacity of ##### t, Full dynamic positioning

Layrate of up to # km a day.

Deepwater pipelay record of ### m (####').

Holding capacity force of #### tonnes

Heerema Balder (operational since ####)

Carrying capacity of ##### t, Full dynamic positioning

Layrate of up to # km a day.

Deepwater pipelay record of ### m (####').

Holding capacity force of #### tonnes

Allseas Solitaire (operational since 1998)

Carrying capacity of 22000 t, Full dynamic positioning

Layrate of up to 9 km a day with in-house Phoenix automatic welding system.

Deepwater pipelay record of 2775 m (9100').

Holding capacity force of 1050 tonnes

New Pipelay Vessels under Construction

- Saipem SpA new laybarge CastorONE, now under construction
- Ready for offshore operations early in 2012. Saipem has confirmed that the MEIDP is feasible and can be installed in a water depth of 3500m

- HMC New Build vessel Aegir, now under construction
- proposed to be complete by mid 2013, ready for offshore operations early in 2014.

- Allseas vessel Pieter Schelte, now under construction
- Proposed to be complete by end 2013, ready for offshore operations in 2014.

Installation Vessel Requirements J-Lay

- J-Lay Vessel Demand
  - 1060tonne normal laying
  - 2000tonne Flooded and abandonment

$T_c = T_d . S_f . S_d$

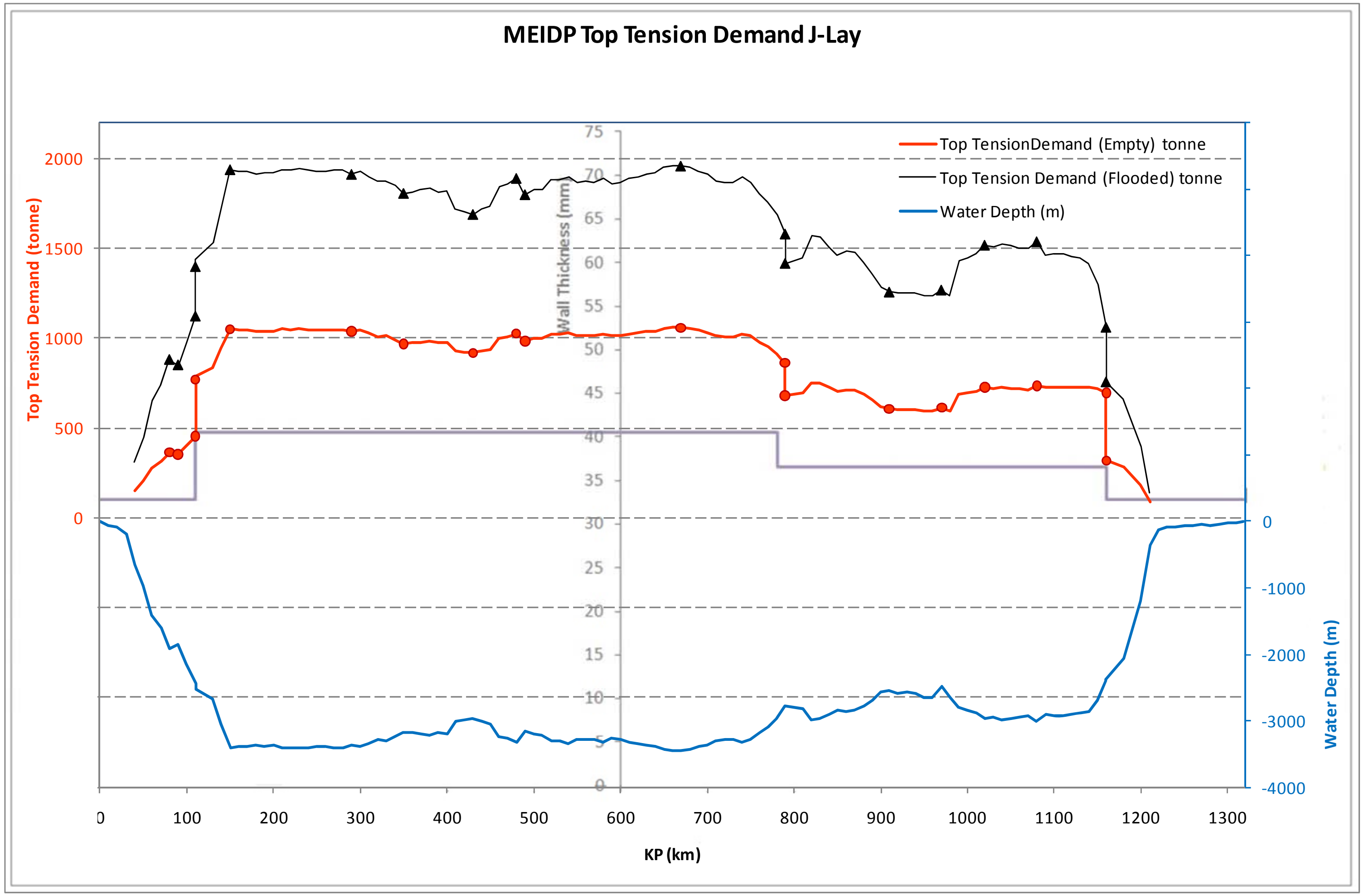
T_d = Tension Demand

T_c = Tension Capacity

S_f = Safety Factor (1.15)

S_d = Dynamic Amplication (1.3)

- J-Lay Vessel Capacity
  - 1600tonne normal Laying
  - 2500tonne flooded and abandonment



Vessel Capability to meet MEIDP Requirements

OPT Series

Empty Pipe

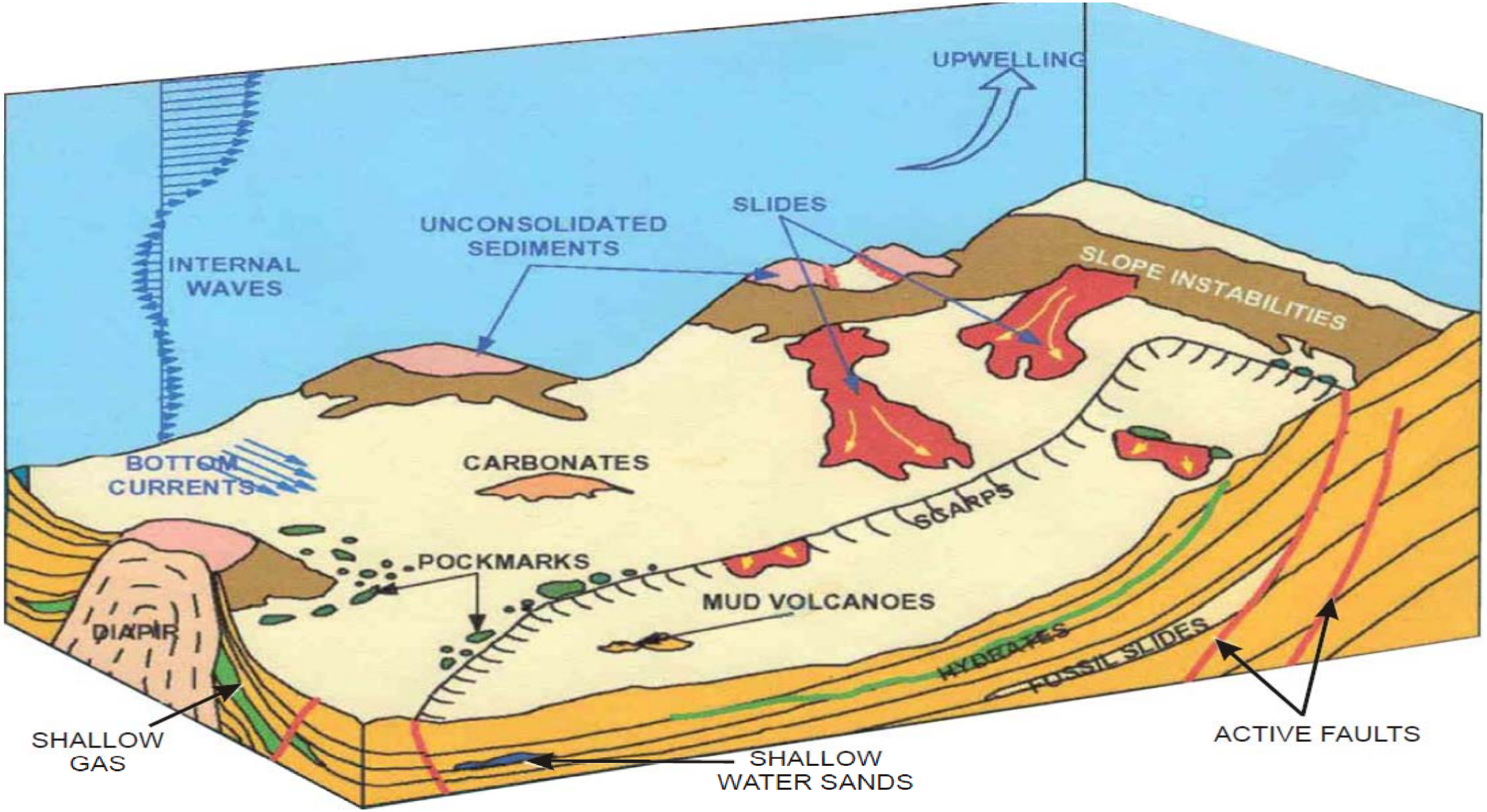
Supplier	Pipe-lay	Vessel Name	MEIDP Size OD Requirement	Vessel Maximum Size OD	Demand Top Tension	Vessel Capacity Requirement	Vessel Capacity
			in	in	mT	mT	mT
Saipem	J-Lay	7000	27.2	32	1075	1607	2000
		CastorOne	27.2	36			2000
HMC		Balder	27.2	32			1210
		Aegir	27.2	32			1500
Saipem	S-Lay	CastorOne	27.2	36	1288	1925	750
Allseas		Pieter Schelte	27.2	68			2000
		Solitaire	27.2	60			1050

Flooded Pipe

Supplier	Pipe-lay	Vessel Name	Demand Top Tension	Vessel Capacity Requirement (DTT*1.3)	Vessel Capacity[1]	Assumed Vessel Capacity
			mT	mT	mT	mT
Saipem	J-Lay	7000	1993	2591	2000	2000
		CastorOne			2500	2500
HMC		Balder			N/A	1500
		Aegir			N/A	1875
Saipem	S-Lay	CastorOne	2781	3615	975	975
Allseas		Pieter Schelte			2000	2500
		Solitaire			N/A	1300

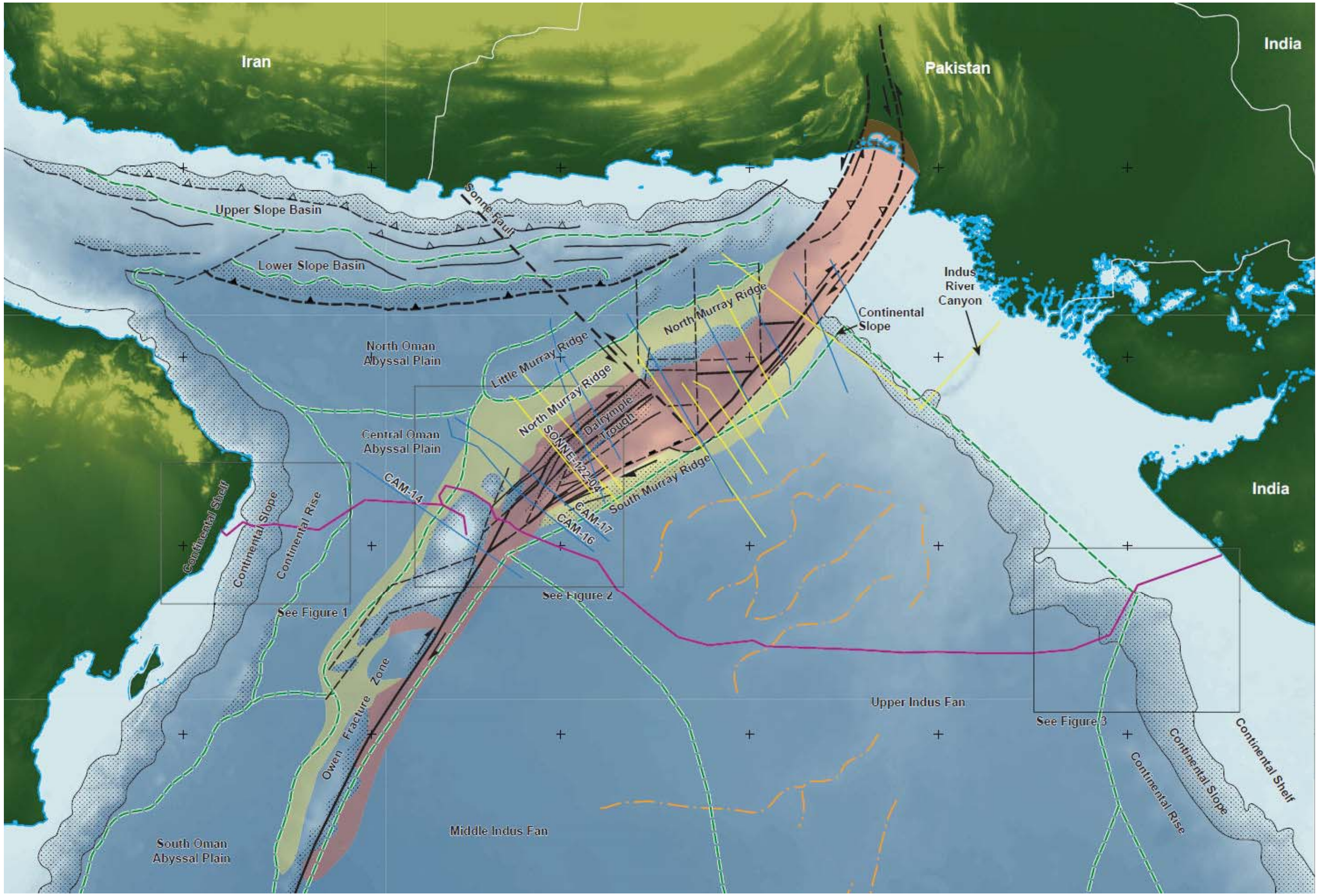
Geohazards

Typical Geohazards for Deepwater Pipelines



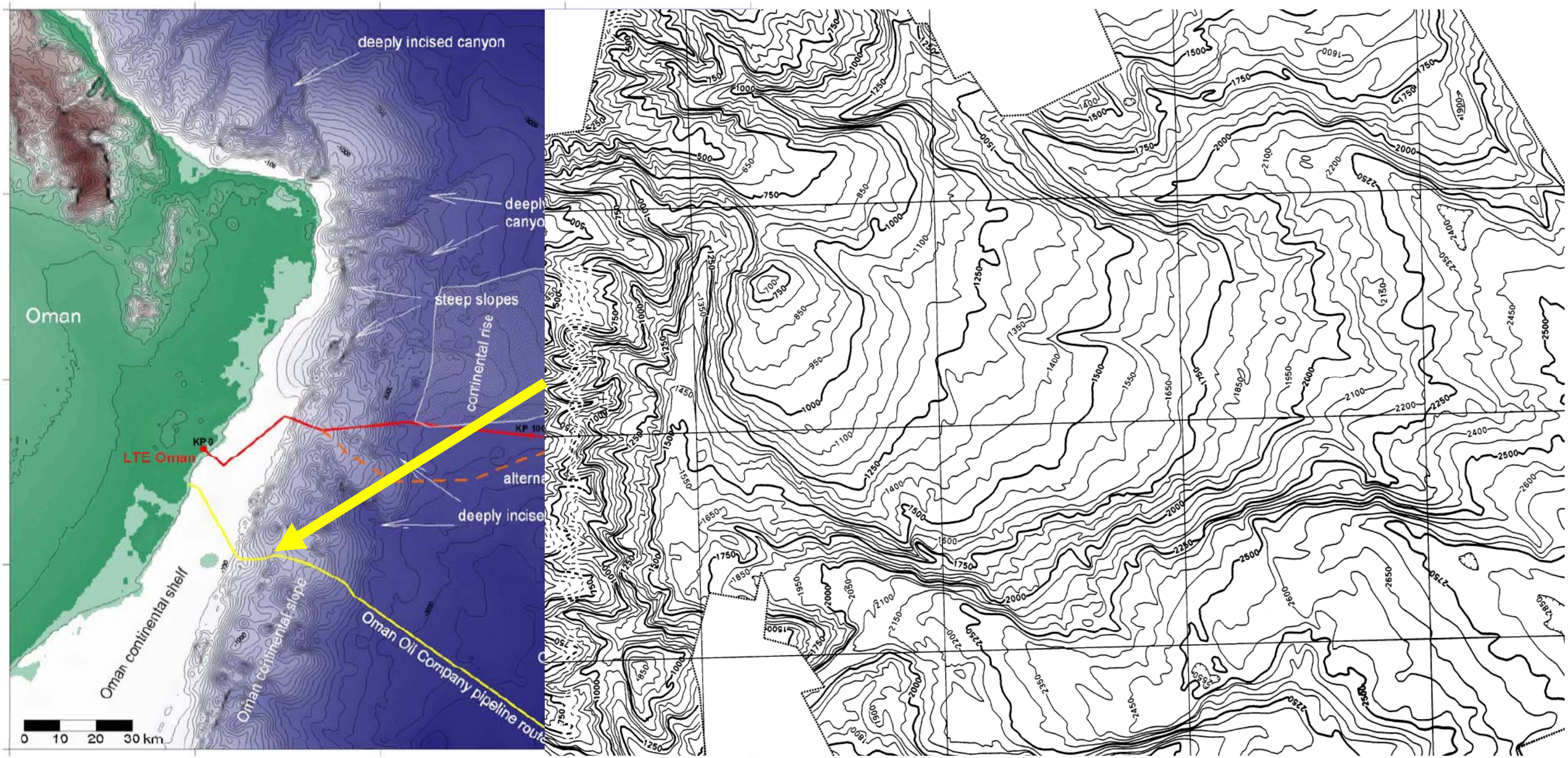
Note: - Modified after Clayton and Power (2002).

Morpho-Techtonic Features



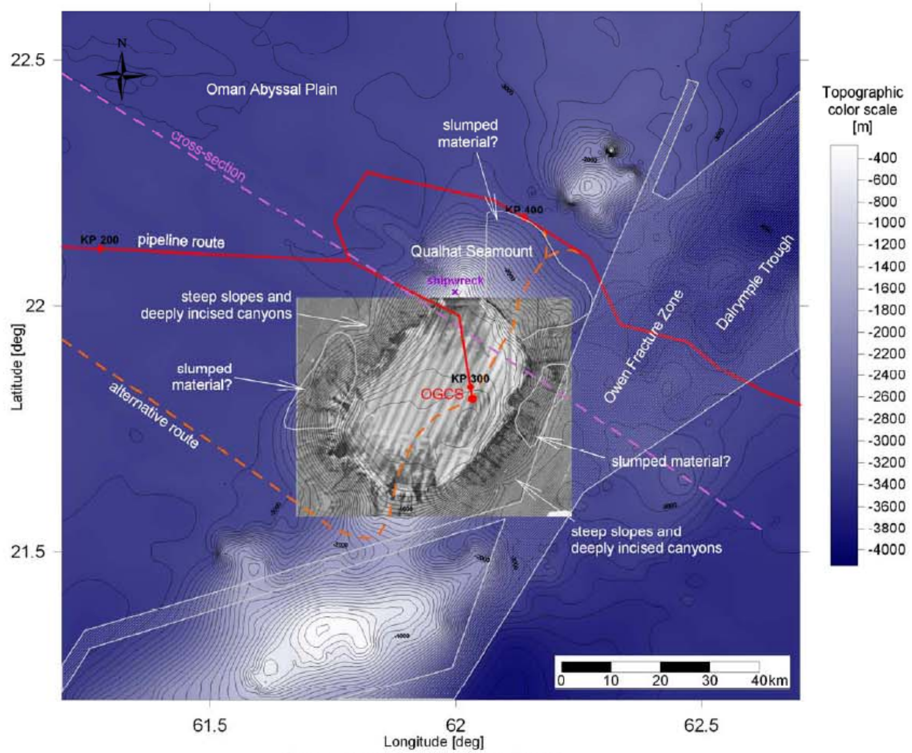
Geohazards and Features offshore Oman

Bathymetry and seafloor features of the Oman Continental Shelf and Slope

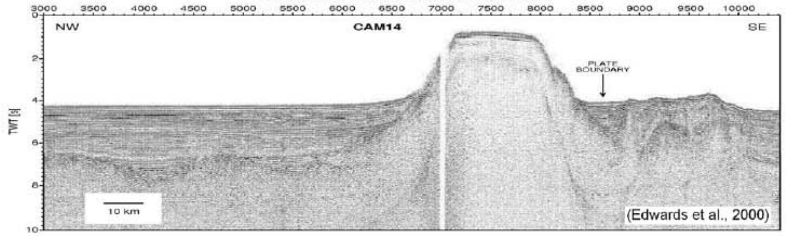


Murray Ridge and Qualhat Seamount

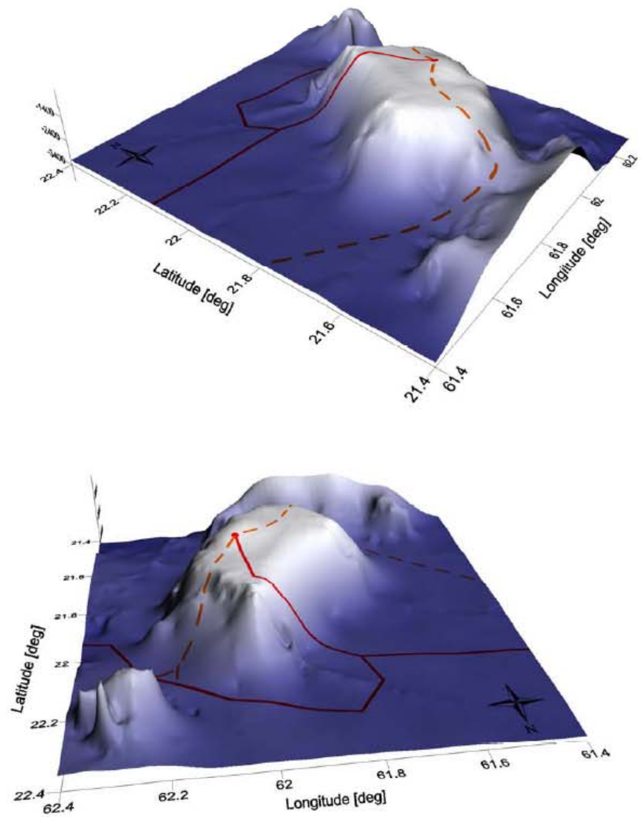
Bathymetry and seafloor features of the Qualhat Seamount



Seismic cross-section CAM14

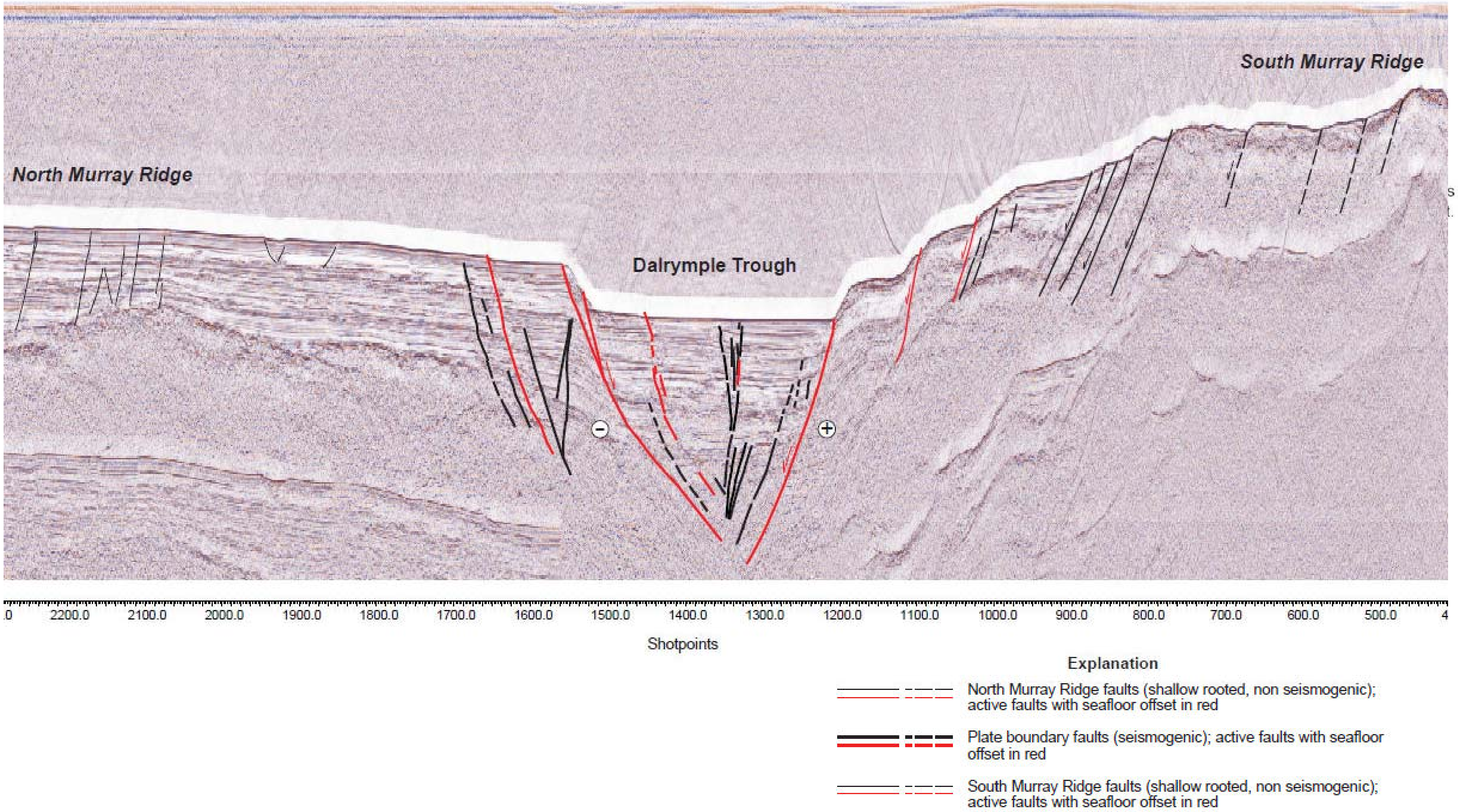


3D-view of the Qualhat Seamount
View to the Northeast and South

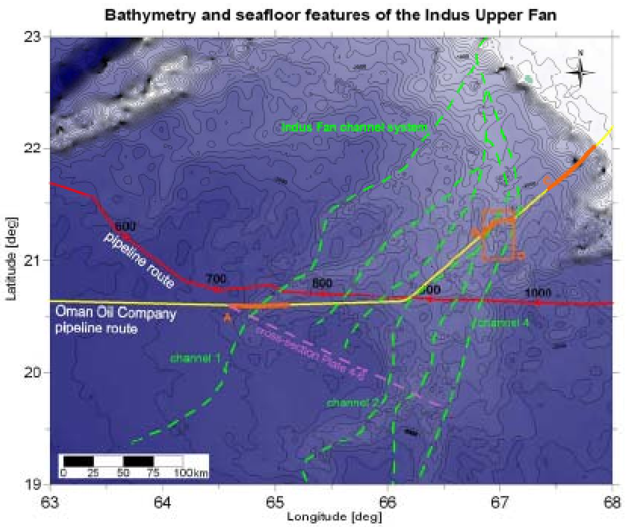


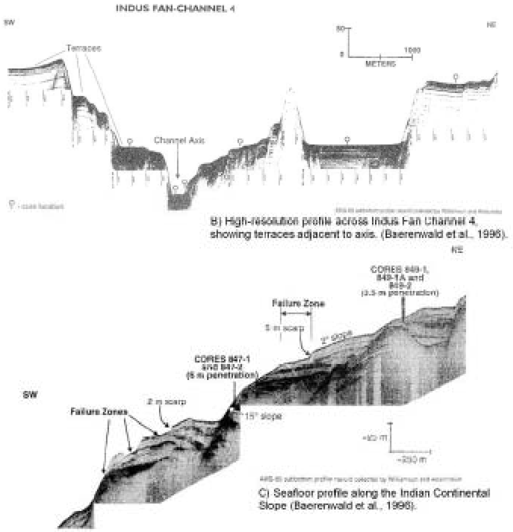
Notes: - Image on map is a multibeam sonar mosaic of the Qualhat Seamount (IFREMER, MARABIE cruises 2000 and 2001)
- Contour interval of bathymetry is 100 metres (derived from GEBCO gridded bathymetry).

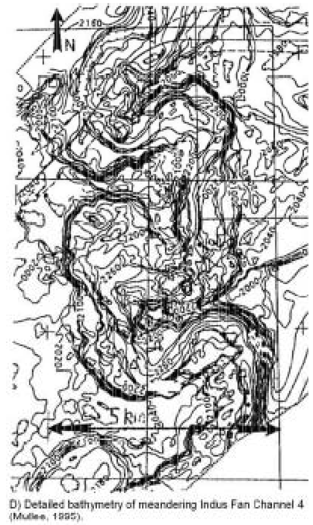
Dalrymple Trough

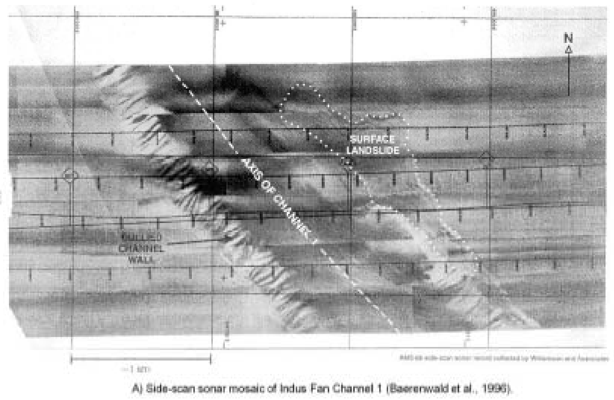


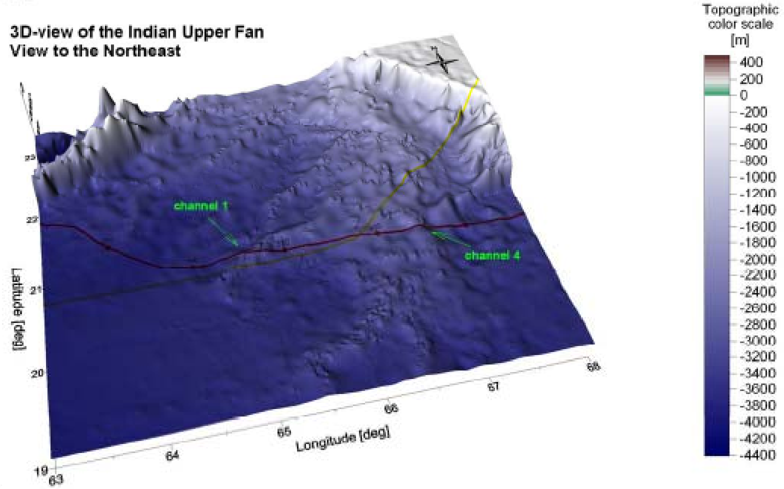
Indus Fan crossing









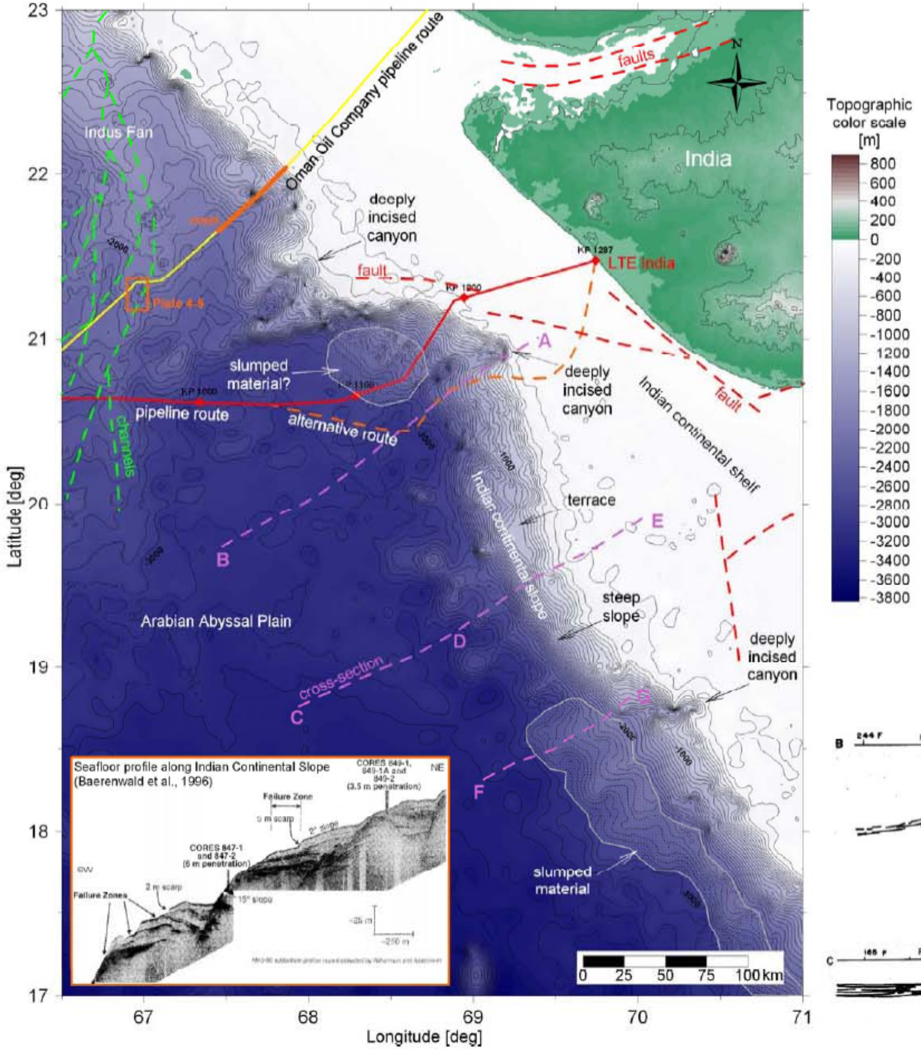


Note: - Contour interval of bathymetry map is 100 metres (derived from GEBCO gridded bathymetry).

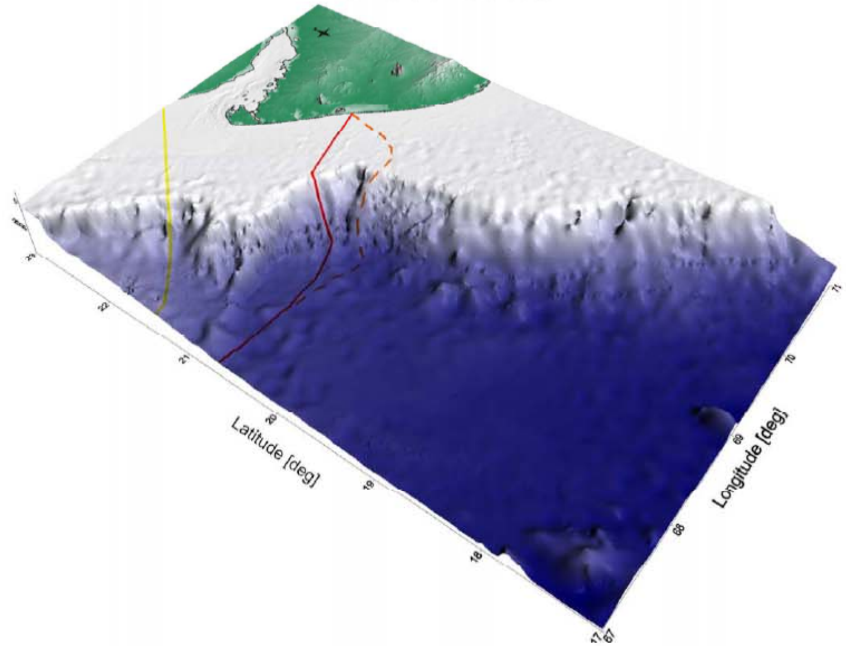
Bathymetry and Seafloor Features of the Arabian Abyssal Plain and Indus Fan
SOUTH ASIA GAS ENTERPRISE (SAGE) PIPELINE – OMAN TO INDIA

Indian Continental Slope

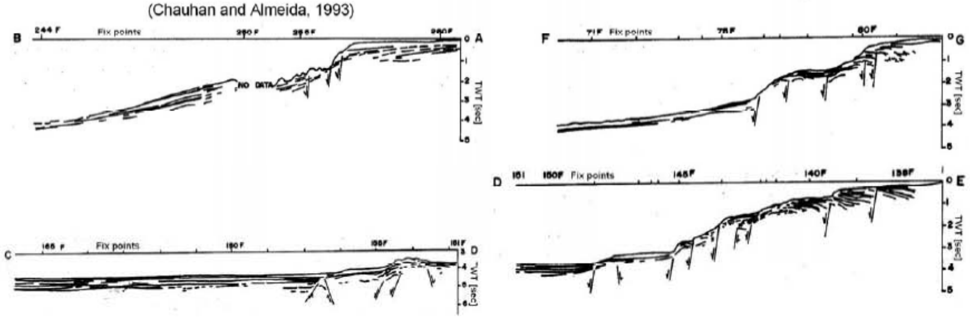
Bathymetry and seafloor features of the Indian Continental Shelf and Slope



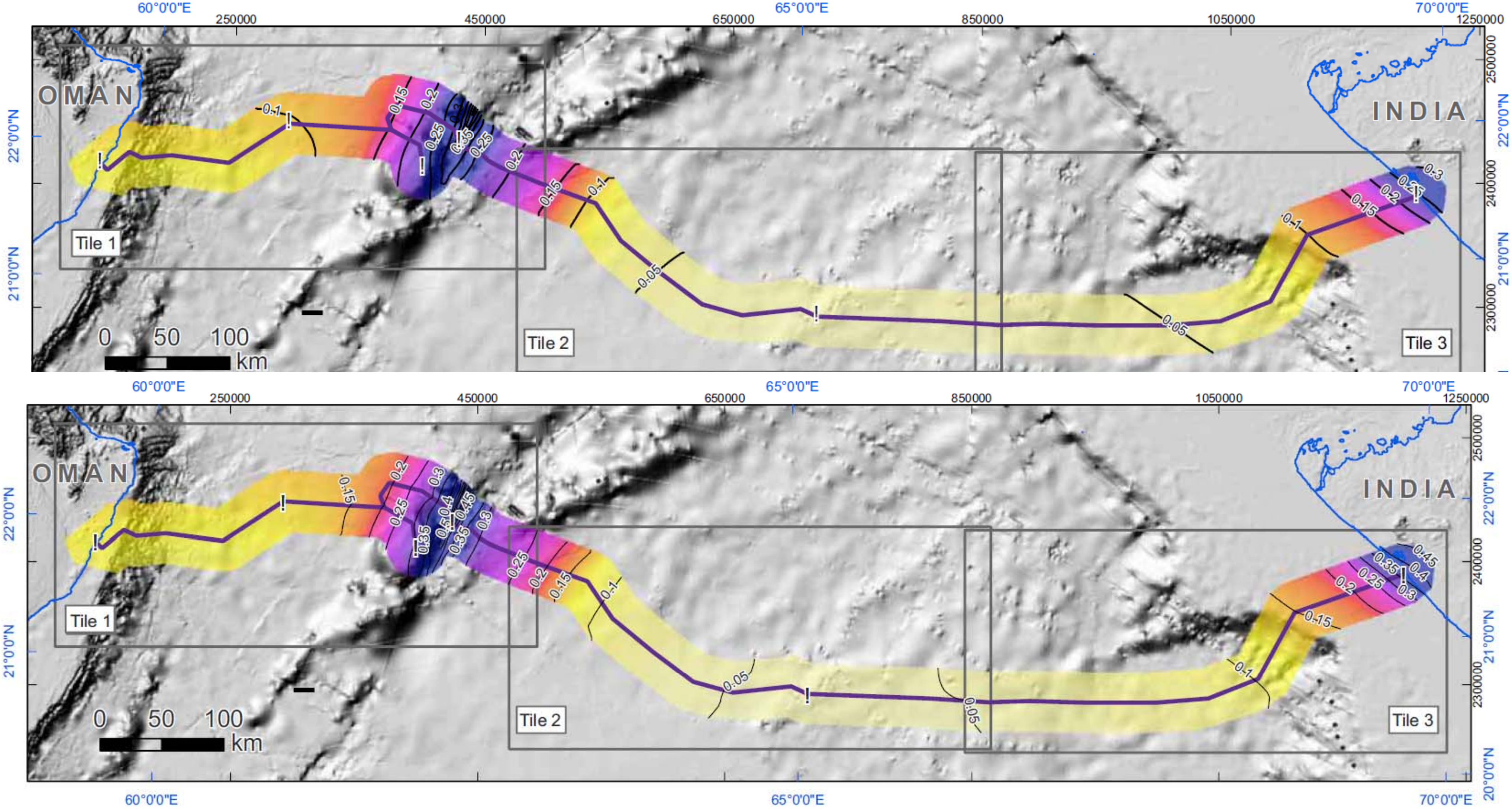
3D-view of the Indian Continental Shelf and Slope
View to the Northeast



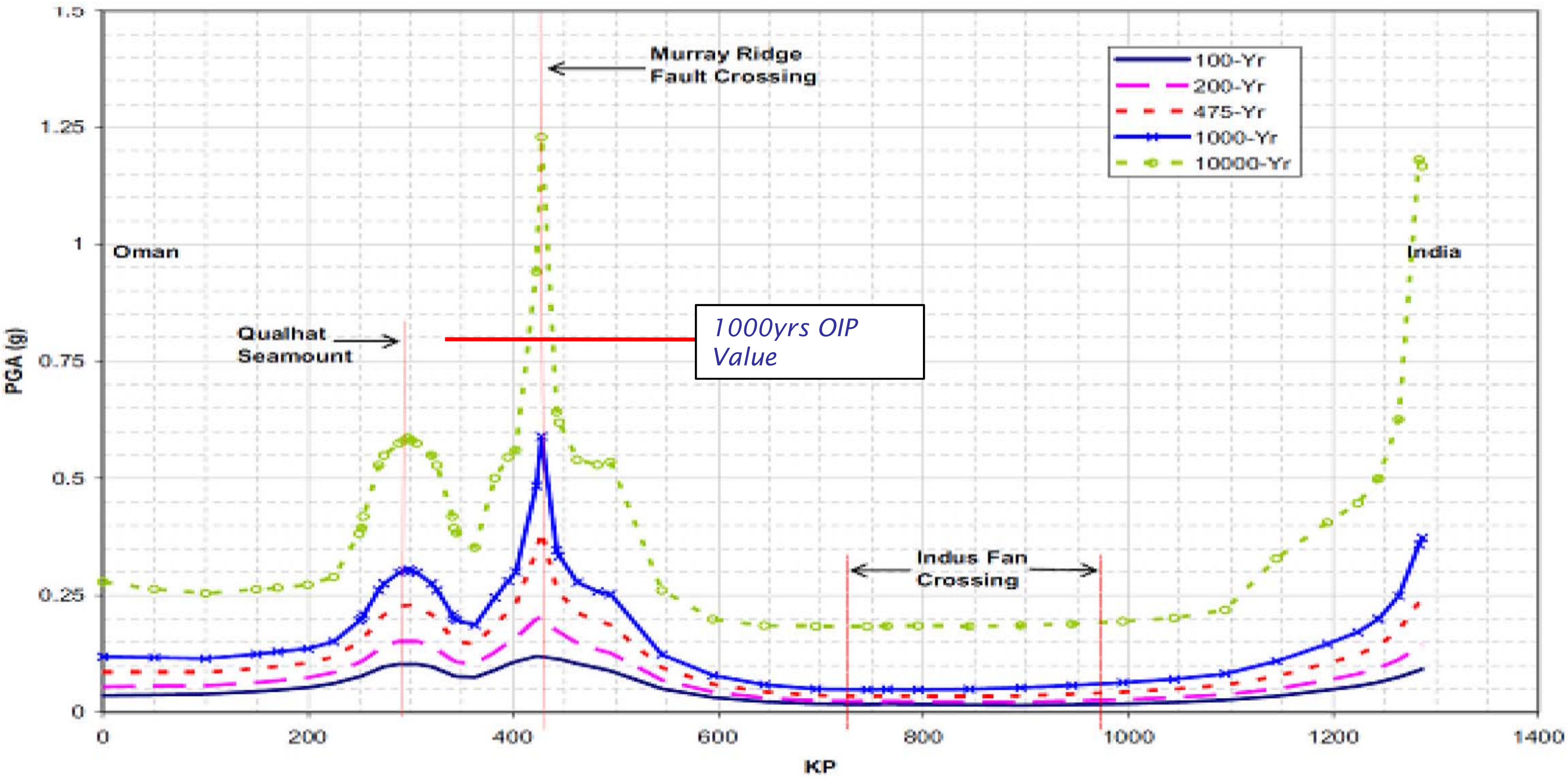
Interpreted seismic cross-sections of the Indian Continental Slope
(Chauhan and Almeida, 1993)



PGA Maps (475yrs & 1000yrs)



PGA Profiles Along Route

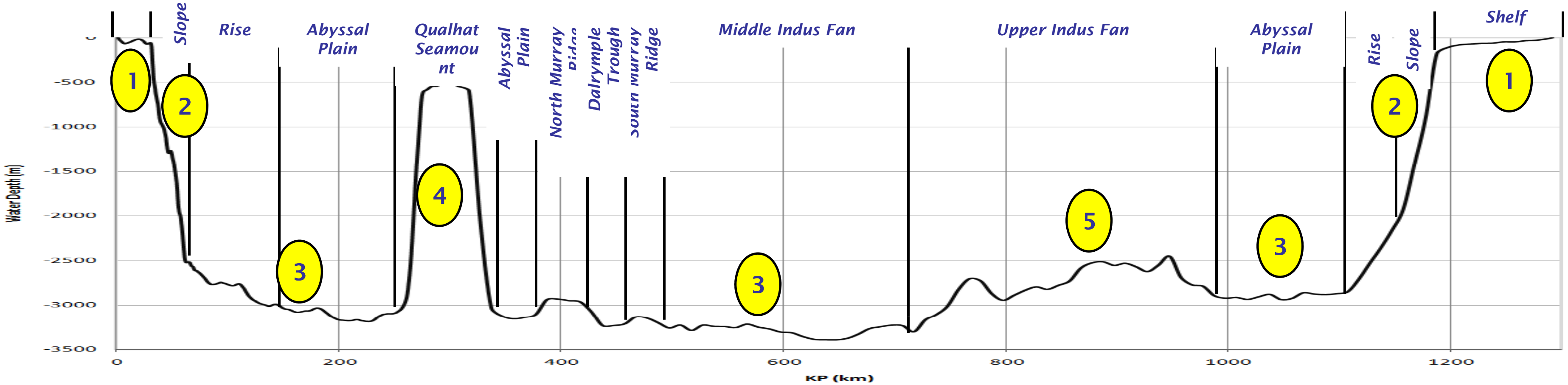


Intervention

Intervention Zones

Based on this preliminary information, the route has been divided into five different intervention requirement zones.

1) Shallow Water Zone (0 to 150m WD)
2) Continental Slope Zone (150m to 2500m WD)
3) Deep Water Section (2500m to 3500m WD)
4) Remote Seamount Section (300m to 3000m WD)
5) Indus Fan Section (2500m to 3000m WD)



Intervention Zones Seabed Conditions

Zone	Location	Soil Properties Summary
1	Oman Continental Shelf	Sands, gravel, reefs and outcrops of limestone, igneous/metamorphic rocks, calcareous silts and well-sorted sands
	India Continental Shelf	Quartz and heavy mineral sands, dark yellowish brown to olive grey silt, clay with shell fragments, light olive grey carbonate sand (oolitic sand) and algal and oolite limestones (or calcarenites)
2	Oman Continental Slope	Olive brown to olive grey very soft to soft pelagic silt and clay
	India Continental Slope	Dark yellowish brown to olive grey fine grained cohesive soils, i.e. silts and clays with shell fragments
3a	Abyssal Plain and Lower Indus Fan	Pelagic sediment of greenish grey to olive grey very soft to soft clay and silt
3b	Owen Fracture	Dark yellowish brown to greenish grey to olive grey very soft to soft pelagic clay and silt
4	Remote Seamount	Dark yellowish brown to greenish grey to olive grey very soft to soft pelagic clay and silt
5	Indus Fan	Yellowish brown to olive grey very soft to soft clay and silt

Intervention Drivers

Intervention works either pre or post lay may be required to mitigate against the following effects along the route:

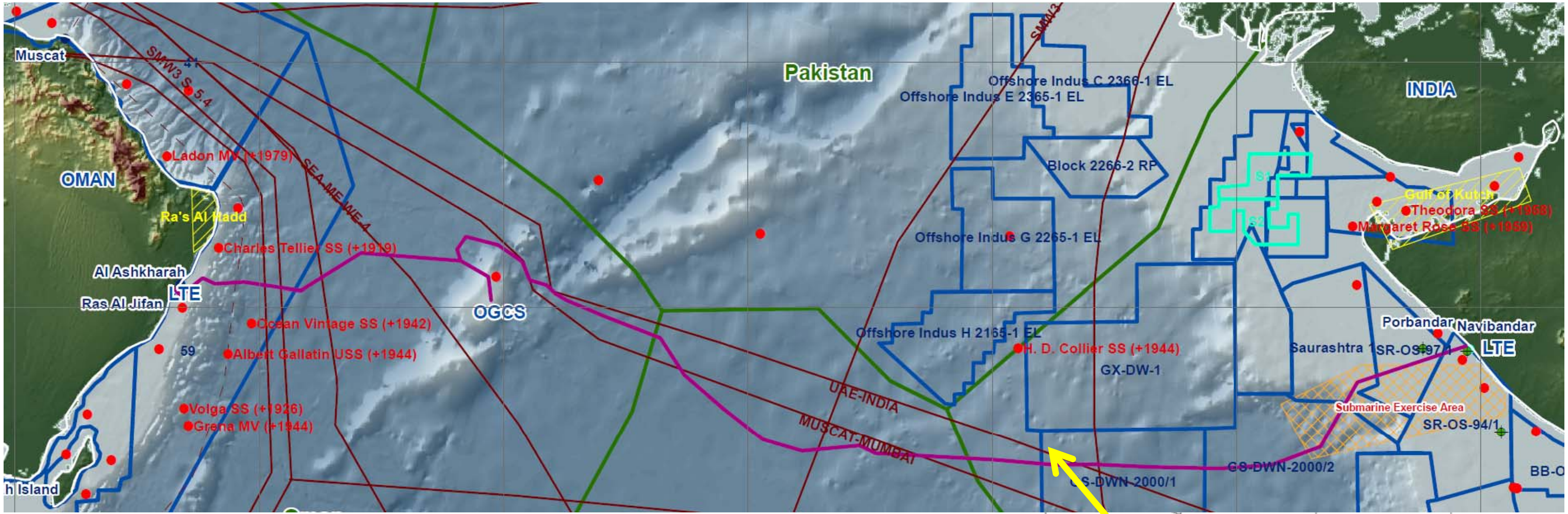
- Geo-hazards
- Bottom roughness
- Free spans
- Slopes
- Stability
- Thermal/pressure buckling
- Crossing

Candidate Techniques for intervention are :

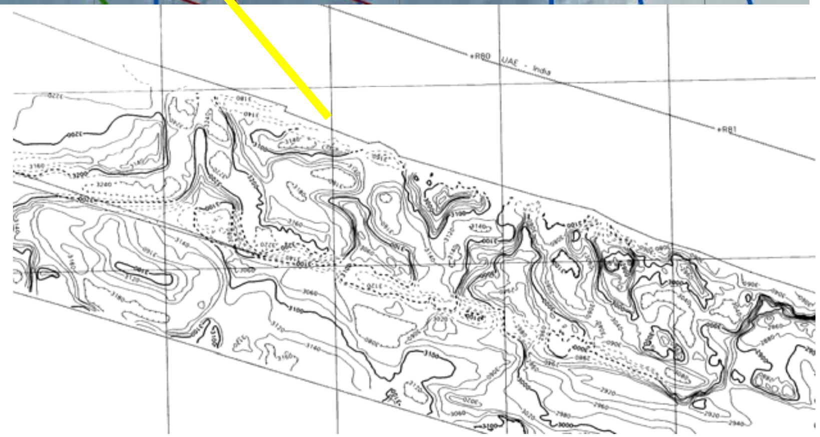
- Dredging
- Trenching
- Rock Dumping
- Mattresses
- Mechanical intervention
- VIV Strakes
- Backfilling
- Trenching
- Rock Dumping
- VIV Strakes

Cable Crossings Along Route

OPT Series



Name	Status
ADEN-BOMBAY 2	Proposed
ADEN-BOMBAY 3	Proposed
ADEN-BOMBAY 4	Proposed
FLAG Seg H and J	Existing
FLAG Seg G and I	Proposed
SEAMEWE3 Segments 5.2, 5.3 and 5.4	Existing
SEAMEWE4	Existing
ADEN-MUSCAT	Proposed
SALALAH-MUSCAT	Existing
MUSCAT-MUMBAI	Existing
UAE-INDIA	Existing
UAE-PAKISTAN	Existing
KARACHI-MUSCAT	Proposed



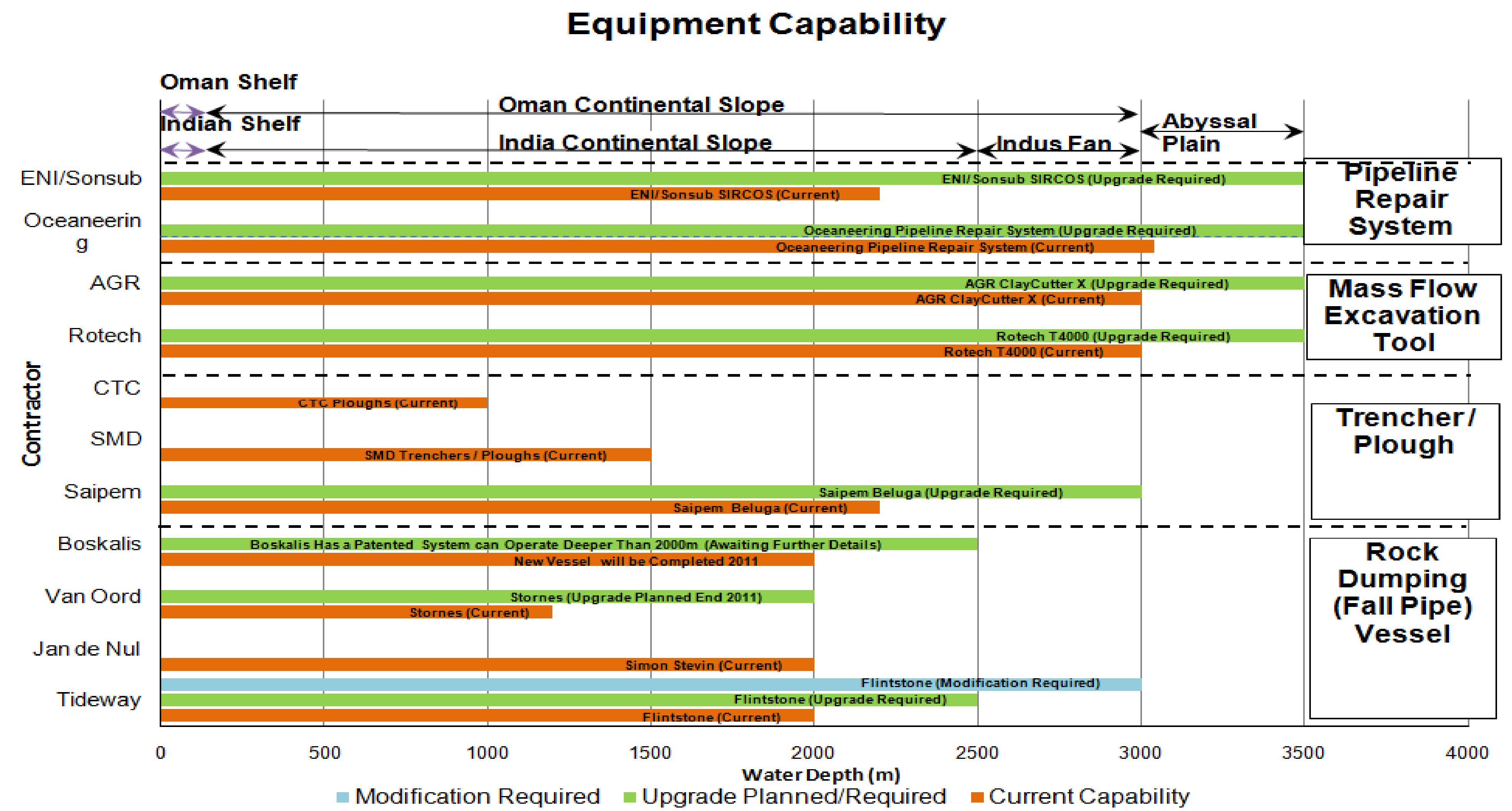
Intervention Methods

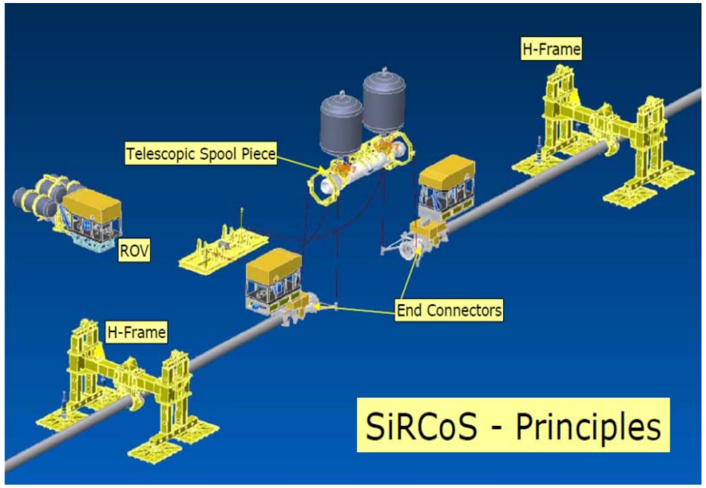
Zone	Intervention Required For	PRE-lay Intervention						Post-lay Intervention				
		Dredging	Trenching	Rock Dumping	Mattresses	Mechanical intervention	VIV Strakes	Backfilling	Trenching	Rock Dumping	VIV Strakes	Pipeline Repair System
1	Stability at Landfall	X						X				
1	Pipeline Stability								X			
1,4	Thermal Buckling					X				X		
1	Ship Anchor Damage								X			
1,4	Fishing Gears Interaction								X			
1,2,3,4,5	Free Spans		X	X			X		X	X	X	
1,2,3,4,5	Pipe Leaks or Local Buckle											X
2,3,4,5	Geohazards		X						X			
2,3,4,5	Pressure Buckling					X				X		
2,3	Crossings			X	X	X						

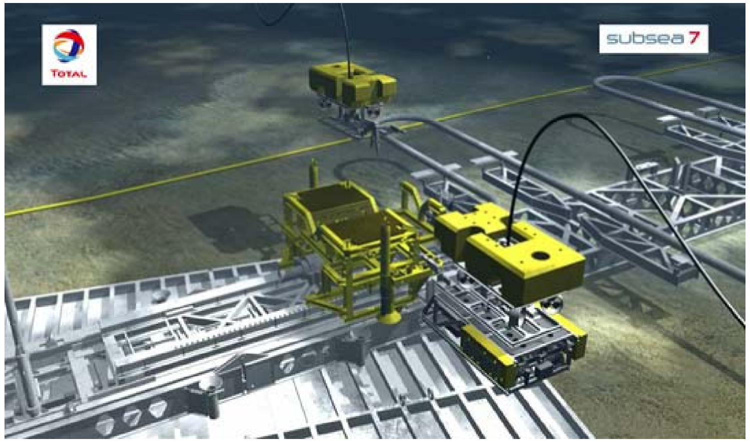
Intervention Equipment Capability Summary

Equipment Type	Depth Requirement	Survey Results	Equipment Modification Plan
Dredging Vessel	Up to 30m	Variety of dredgers available in the market can dredge up to 30m WD	Not Required
Rock Dumping (Fall Pipe) Vessel	Up to 3500m	Current max. working depth is 2000m. Following are currently most capable vessels in the market can work up to 2000m. Simon Stevin (Jan de Nul) Flintstone (Tideway) – new vessel, to be operational from May 2011 Unknown Name (Boskalis) – new vessel, to be completed in 2011 Stornes (Van Oord) – new vessel, to be operational from March 2011 with depth limit of 1200m. Upgrade is planned to bring the working depth to 2000m by end of 2011.	Tideway indicates modification to bring working limit to 3500m is possible and that could be planned and ready for 2015. Jan de Nul and Van Oord indicate major issues of extending the working depth to 3500m is the vessel structure must be adequate to support the increased fall pipe weight; vessel must also have enough space to store the extra fall pipes. These issues shall be looked at and qualification may be required to verify the design as this is a major step change.
Plough (Trenching)	Up to 3000m	Most ploughs currently only able to work up to 1000m	Cannot be upgraded to 3000m as it is too deep for this mode of trenching technique.
Trenching Machine		Most trenchers are rated up to 1500m. However, Saipem's Beluga can work up to 2200m.	Saipem indicates Beluga can be upgraded for higher water depth
Mass Flow Excavation Tool (Trenching)		Rotech and AGR indicate their excavation tools are rated up to 3000m. T4000 (Rotech) & ClayCutterX (AGR)	Both Rotech and AGR indicate modification to bring the working depth to 3500m is possible (if required), though design and deployment will need to be looked at.

Intervention Vessels and Equipment Capabilities







Repair Systems

Damage Category and Scenario

Phase	Damage Category	Specific Damage Scenario
Installation	Dry Buckle	Dry Local Buckle Dry Propagating Buckle
	Wet Buckle	Wet Buckle
Operation	Hydrate	Hydrate
	Localized Damage, No Leak	Internal/External Corrosion Gouge Dent/Buckle Overstressing Fatigue Damage Trawling Anchoring Objects Dropped from Ships Ship Sinking Ship Grounding Shipwrecks and Debris Earthquakes Mass Gravity Flows and Turbidity Currents Tsunami
	Localized Damage, Minor Leak	Pinhole Leak Seismic Fault Submarine Landslips Liquefaction Scour
	Rupture, Local	Rupture Earthquakes Slope Stability
	Rupture, Extensive Length -or- Extensive Damage, No Leak	Rupture -or- Internal/External Corrosion

Emergency Pipeline Repair System

The functional requirements identified for an MEIDP emergency repair system are listed as follows. The requirements are a minimal set and that should be developed further in future stages of the project.

- Functional requirements of the emergency repair system:
- Operable at water depths up to 3500m.
- Operable on 24" internal diameter pipelines.
- Operable with steel wall thickness up to 40 mm and relevant coatings.
- Operable on seabed soils of soft calcareous clay and silt.
- Operable on seabed slopes of up to 28 degrees.
- Capable of providing a repair capability extending from minor dents to replacement of multiple pipe joints.

While not mandatory, it is advantageous if the system(s) and equipment also exhibit the following characteristics:

- Modular and/or lightweight.
- Minimum number of components.
- Incur minimal shut down and/or reduction of operation.
- Minimum CAPEX investment.

Repair System Components

An overall pipeline repair system to install a clamp or spool requires an extensive array of equipment to conduct a repair operation. The repair systems generally perform tasks from the following list:

- Metrology of the pipeline damage and repair site.
- Isolation of the damaged section of pipe with internal plugs if required.
- Soil excavation.
- Pipeline lifting: locally at the repair site or completely to the surface.
- Pipe coating removal.
- Pipe cutting.
- Removal of damaged section.
- Pipe end surface preparation.
- Metrology of the pipeline for clamp and spool piece preparation.
- Transport and positioning of clamps, spool pieces and connectors.
- Closing and sealing clamps and connectors.
- Testing the repair.
- Lower the pipeline to the seabed.
- Removal of repair system equipment.

Why Tooling is Needed

Equipment	Purpose
DP Support Vessel	Platform from which to operate ROV's and conduct repair operations.
Pipelay Vessel	Working platform in the event that an extensive section of damaged pipeline has to be relaid/replaced.
Flooding/Dewatering/Drying Spread	Various purposes including: • Pressure equalisation prior to cutting (flooding). • Coupling for intelligent pigging (flooding). • Removal of water (dewatering). • Drying prior to returning to service to minimise water content and risk of hydrates.
Seabed Dredging/Levelling Equipment	Exposure of the pipeline, if locally trenched or buried, to allow for survey and/or repair operations.
Pipeline Lifting Frames	Elevation of pipeline off the seabed in the vicinity of any repair, for the purpose of improving access for repair equipment and operations.
Subsea Measurement Tool	Performance of measurements between pipeline ends for accurate spool piece and connector assembly.
Pipeline Cutting Tool	Cutting of pipeline (and coatings) to allow removal of any damaged sections.
Pipeline Coating Removal Tool	Removal of external pipeline coatings in the vicinity of any section that has been cut (by the Pipeline Cutting Tool). Required in the event that the Pipeline Recovery Tool grips the pipeline on its external steel surface.
External Weld Bead Removal Tool	Removal of external longitudinal weld seam (SAW linepipe) to prevent interference on connector seal.
End Preparation Tool	Machining of the end face of the pipeline to prevent interference on connector seal.
Pipeline Recovery Tool	Tool connected to the end of the cut pipeline to allow recovery to surface. Designed to allow the pipeline be dewatered and isolated prior to recovery.
Pipeline Repair Clamp	Permanent clamp installed around the pipeline in the vicinity of minor damage (i.e. dent) for the purpose of ensuring the structural integrity of the pipeline without the need for cutting out and replacing an entire section of pipe.
Subsea Pipeline Connectors	Connector assembly and modular system used for the installation and connection of a new section of pipeline.
Replacement Spool piece	New section of pipeline used to replace area of damage.
Hydrate Blockage Removal Spread	Accidental ingress of moisture into the pipeline can cause formation of a hydrate plug. Hydrate removal is possible by various passive methods but may ultimately require a deepwater hot-tap operation at actual location of the hydrate where the spread taps a hole into the pipeline and injects hydrate removal chemicals.

Example Lifting Frame

Damage Equipment Matrix

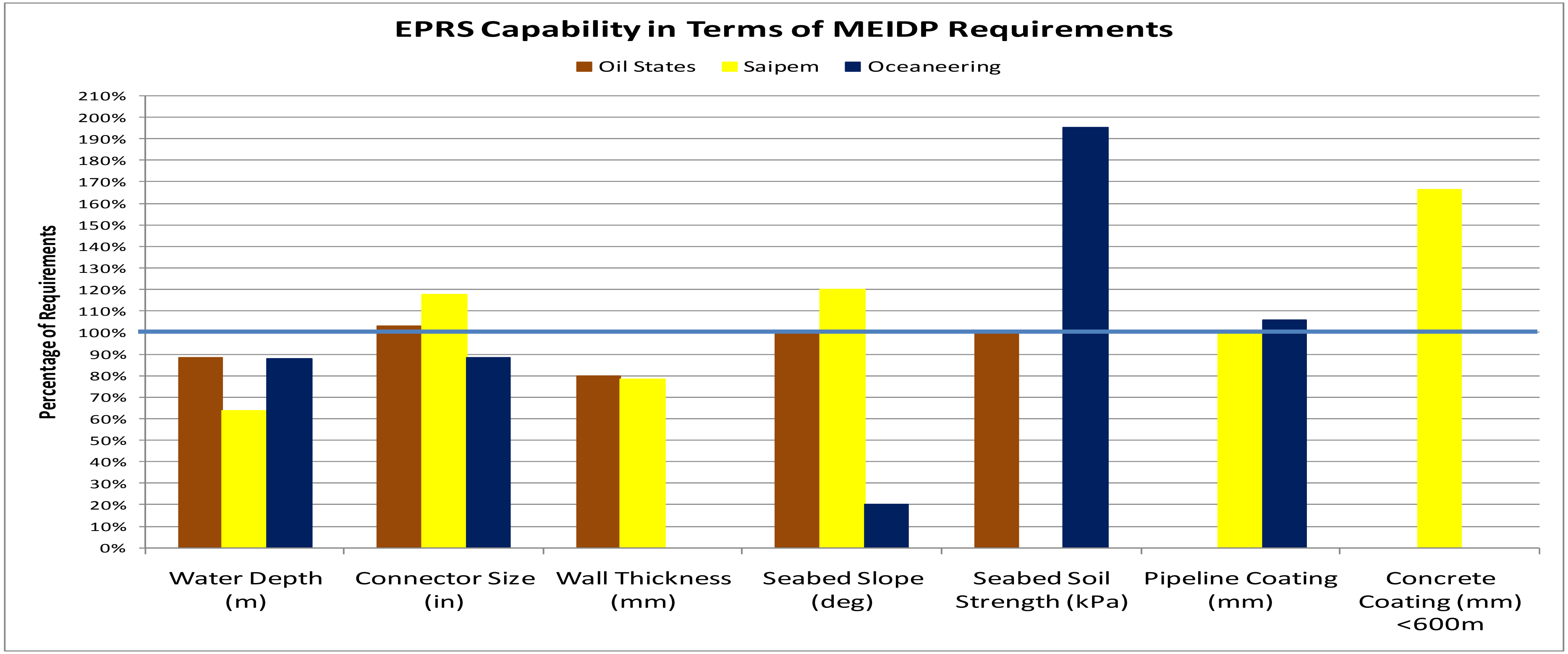
	Pipelay Vessel	ROV Support Vessel	Flooding/Dewatering / Drying Spread (Onshore)	Deep Water Repair System Components							Seabed Dredging / Levelling Equipment	Hydrate Removal Spread	Intelligent Pigging Equipment	Repair Clamp (i.e. Split Sleeve)
				Pipe Lifting Device (i.e. H-frames)	Pipe Cutting Tool	Coating Removal Tool	Pipeline Recovery Tool (with d/w capability)	Metrology Unit	Weld Bead Removal Tool	Connection System and Spoolpiece				
Dry Local Buckle (recoverable)	✓	✓												
Dry Local Buckle (non-recoverable)	✓	✓	✓	✓	✓	✓	✓							
Dry Propagating Buckle (non-recoverable)	✓	✓	✓	✓	✓	✓	✓							
Local Wet Buckle (non-recoverable)	✓	✓	✓	✓	✓	✓	✓							
Hydrate plug												✓		
Localised damage, no leak		✓									✓		✓	
Localised damage with leak		✓		✓		✓					✓	✓		✓
Rupture, local		✓	✓	✓	✓	✓		✓	✓	✓	✓			
Rupture, extensive length	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			

Repair Systems and Clubs

Equipment Name	Main Contractor / Operator
Bespoke Systems	
Chevron Petronius Repair System	Oil States / Chevron
BP Mardi Gras Pipeline Repair System	**Oil States / BP**
SIRCOS	**ENI / Saipem (Sonsub)**
Pipeline Connection and Repair Systems (PCRS)	**Oceaneering**
Total Girassol Pipeline Repair System	Subsea 7
Repair Clubs	
Shell Deepwater Pipeline Repair System	Shell HOLD (there are two version of the Shell club?)
DW RUPE	DW RUPE
Pipeline Repair System Pool	Technip (Norway), Deep Ocean, Statoil
Newly Founded Repair Clubs	
Emergency Pipeline Repair Equipment Sharing (EPRES)	South East Asia Pipeline Operators Group (SEAPOG)
	Pipeline Repair Operators Forum Australasia (PROFA)

Candidate Systems Capability

Pipeline Repair Systems	Up to 3500m	Sonsub's SIRCOS currently can work up to 2200m Deepwater Pipeline Repair System from Oceaneering and Oil States currently rated to about 3000m.	Saipem indicates it can be upgraded for higher water depths Oceaneering indicates depth requirement of 3500m can be designed and manufactured Oil States indicates further tests are required to re-qualify their system for 3500m rating



Case Study Summary

- The progress into the water depths expected for MEIDP are no longer a giant leap forward, but rather the logical next step
- The development of deepwater pipelay vessels capable of installing MEIDP and due for commissioning in 2013, will provide the required equipment to install MEIDP
- The development of deepwater intervention vessels capable of meeting the requirements of the MEIDP project is thought to be possible provided adequate schedule is allowed to enable full scale testing and trials
- Emergency pipeline repair systems exist within today for very deep water remote intervention in the pipe size/wall thickness combinations required for MEIDP minor modifications and further development will be required,
- Routes have been established from Oman to India that give options for a midline compression station and avoid the worst features of the Indus Fan, minimising project technical risks

Acknowledgements

The authors would like to thank South Asia Gas Enterprise PVT Ltd. for giving permission to publish this work, the team in Peritus, for their continued hard work on the project, DNV, Fugro GEOS, Fugro William Lettis for their contributions and support.

References

- I Nash & P Roberts OPT 2011, MEIDP The Deepwater Gas Route to India, February 23-24,
- I Nash & P Roberts OTC 2011, MEIDP The Deep Sea Gas Route to India, May 2-5
- Saipem Vessel Data Castorone
  http://www.saipem.it/site/article.jsp?idArticle=5420&instance=2&node=2012&channel=2&ext=template/37DueColonne&int=article/1DefaultArticolo
- HMC Vessel Data Aegir
  http://hmc.heerema.com/tabid/1838/language/en-US/Default.aspx
- Allseas Vessel Data Pieter Schelte
  http://www.allseas.com/uk/19/equipment/pieter-schelte.html