AUV Expanding the Dynamic of Geophysical Survey

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Introduction of Advantages of AUV

Improved Application of AUV through Example Projects

Issues and Improvement of Existing Payload System

AUV Survey for Unconventional Application
Deep Water Challenges
Geophysical Survey

SURFACE - TOW SPARKER DATA

Deep- TOW Chirp Profiling DATA
Deep Water Challenges
Geophysical Survey

Complicated survey operation
Sub-sea positioning issues
Slow and Costly Production

Deep Water Challenges
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Slow and Costly Production
AUV Survey Advantage:
Non-linear Survey Pattern

SIDE-SCAN SONAR MOSAIC
AND WATER-DEPTH MAP
FROM AUV CIRCULAR SURVEY
AUV Survey
Consistently Good Quality Data

Key Success Factor to AUV Survey:

• Extremely quite and stable platform – Data Quality Assurance
• Advance Positioning System - Reliable and Accurate
• Free swimming – Highly Flexibility and Time Saving
AUV Data - Detail Engineering Quality

Hull Mounted Multibeam

AUV Multibeam Data
AUV: Not the Best Deep Water Survey Approach

Only Starting;
Getting Better
Challenges:

• Going through a major seabed through, 3,000m maximum water depth
• Steep & complex slopes between 150m – 1,000m; and 2,000m to 3,000m
• Sediment movement along slopes is evident
• Limited data available for potential route selection
Regional Hull Mounted Multibeam Echo Sounder Survey:

- Multiple survey campaign using different sounding equipment (for different depth ranges)
- Multiple data sets of different quality, accuracy and resolution

=> Multiple routes were proposed based solely on seabed topography
=> Slope stability evaluated from potential sediment flow patterns
Project Example A: Phase 2 AUV Surveys

- **Multiple AUV Survey Passes:**
  - **Exploratory AUV survey** – wide survey corridor, high altitude AUV survey (5m bin) => Route selection and improvement
  - **Detail AUV survey** – reduced corridor, low altitude AUV survey (1m bin) => Route finalised with engineering quality data for design
  - **AUV imaging survey** – still photograph at 3-5m altitude
AUV depth 1085m; Altitude 3.0m
Project Example A: Phase 3 Add-on Surveys

Additional / Supporting Surveys:
• Gravity coring locations based on AUV results
  => Detail stratigraphic analysis & age dating carried out
• Hi-resolution 2D seismic surveys
  => Design along potential faulting areas
Effective & Efficient Used of AUV:
- AUV survey designed for specific purpose & objectives
- Providing results and information that were hard to achieve from a single survey campaign

AUV changes the Dynamic of Geophysical Survey
Project Example B: AUV Micro-3D Survey

Challenges:

- Planning of suction anchors within an area where gas seepages and minor fault systems are evident
- Detail mapping of faults, plus any hidden sub-seabed issues are required for planning and design
- 1,000m water depths
Project Example B: AUV Micro-3D Survey

- A micro 3D Sub-bottom Profiling Survey were performed

Anchor locations
AUV 3Dm Micro Subbottom Survey

- Ultra subbottom density for postage stamp size areas 390 x 500m
- **50 times more subbottom data density** @ 4 meter line spacing
- Includes SGY 3D cube final product
- Line spacing 2 – 4m; at 20m above seafloor
- 16 hours survey time @ 4 knots speed

Benefits sub-seabed piles, suction anchors & drilling locations by providing **exponential level of sub-bottom detail**
AUV 3Dm Micro Chair-cut Result

Bin size 0.5m x 4m
AUV 3Dm Micro Cross Section Profile

- Each **movie frame** is one subbottom line profile at 4 meter line spacing

**OTC 23950**

AUV3Dm: Detailed Characterization of Shallow Soil Strata and Geohazards Using AUV Subbottom Profiler 3-D Micro Volumes

AUV 3D micro surveys

- Example application (ref. George and Cauquil, 2007)

  Detailed pockmark investigation offshore Nigeria
  - Combined close spaced AUV data with 3D seismic data
  - Used to evaluate the development process of pockmarks

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AUV 3D micro survey – Applications

At least 17 deep water AUV3Dm surveys known to have successfully completed to date; some of the objectives achieved include:

1. Characterize or avoid fault planes in production - facility foundation zones;
2. Characterize fluid vents (pock marks and mud volcanoes) and gassy zones;
3. Detect boulders; and
4. AUV3Dm time-lapse (4-D) surveys to detect changes at a fluid-vent site.
Stevenson and others, as early as 2002 suggested AUV would provide a **stable platform** for 3D micro survey.

However successful program depends on very high positional accuracy – **details matter, a lot!**

1. **Navigation** of the AUV to maintain straight track-lines and uniform track-line spacing;
2. **Accurate positioning** of the AUV/SBP transducer;
3. **Survey-line plan** (shooting sequence and direction);
4. **Tidal (depth) and atmospheric (pressure) changes** to correct for variations in AUV height above seabed;
5. **Migration of data** during 3-D seismic processing
Barometric Compensation

- Digitally log barometric surface pressure & apply to each MBE & SBP ping
- **Benefit is a better quality seabed terrain & sub-bottom profiles**
- 15cm of relative depth error is large
- Critical for AUV3Dm project
- Routine application for all AUV survey
Improved AUV Depth Calculations

- Hardware and software upgrade
- More responsive in dynamic seafloor areas
- Higher quality multibeam data
- Higher quality subbottom data
- Clearer micro 3D subbottom images & cubes
- In service as of Q1, 2013
High Resolution Satellite Tides

- Calculated on site – not interpolate or extrapolate from other tide station
- Based on TPX07 Oregon State University and regional models
- Recently applied to Fugro’s AUV Micro 3D survey with 10cm relative results
- **Benefits** multibeam & subbottom data quality for open ocean surveys
- Extensive comparison studies have been completed in many regions including **North America**, South America & Africa.
Existing AUV Payloads

Issues & Improvements
AUV Sub-Bottom Profiling Issues

Questionable Chirp SBP performance & penetration

Seabed ➔

Old SBP Technology

StarPulse Technology

• Improved data acquisition algorithm
• Increase pulse length & lowering center frequency
• Increase penetration and retain resolution

Seabed ➔

StarPulse Technology

Optional to combine with Sub-bottom Multi Pulse (SMP)
Sub-bottom Multi Pulse (SMP)

- **Two different frequency pulses** are transmitted in an alternating pattern
- Higher resolution data in the shallow sub-bottom section (up to 16 kHz) - **benefits pipeline route surveys**
- Deeper penetration with lower frequency (2 kHz) - **benefits sub-seabed piles and suction anchors**
  - Trade off is less pings in long-track axis for any given frequency
- Multi ping is a excellent trade off, because data is normally overly dense in long-track direction
- Delivered in two standard SGY files
Multi Pulse Data Example

• 2 frequency data acquired at the same time during an AUV survey
• Low frequency – deep penetration 40% more (top)
• High frequency – high resolution (bottom)
• Vertical Scale in milliseconds

Seabed

Seabed
Towed AUV Mini Streamer – Future Development

• 15 - 40 channel streamer
• Deep penetration to supplement geotechnical coring results
• Resolve seabed variability
• Potentially determine porosity, density, S-wave and P-wave
Synthetic Aperture Sonar (SAS) sub-bottom profiling

- Taking the advantage of AUV being a stable platform
- Combines many acoustic pings to form an subsea image
- Several times higher long-track resolution from seabed down to 5 meters
- Compliments gravity coring information
- Benefits pipeline routes and other seafloor infrastructure type surveys
- Sea-trial in Q4, 2013
Mapping Water Column Anomalies

- Achieved through Enhanced Water Column (EWC)
- Use sidescan SONAR water column data to detect gas bubbles
- Showing gas seepage in direct relation to sub-bottom profiling section
- Strengthens both sidescan & subbottom data sets for interpretation
- Have seen bubbles up to 2900 meters water depth
- R&D with hardware vendor to further enhance detection method
Enhanced Water Column (EWC) Final Product

Water Column Anomaly

Water Column from Sidescan Sonar

500 ft

~25 ft
Upgrade AUV Sidescan Sonar Frequencies

AUV, a **stable platform** enabling the upgrades, and future developments!

- **120 kHz (current)**
- **410 kHz (current)**
- **240 kHz (upgrade)**
- **540 kHz (upgrade)**
- **1600 kHz (upgrade)**

Investigation purposes
Low altitude only

100 x 20 meters
AUV Environmental Datasets

- Value added information extracted from existing sensors being part of AUV navigation system
- Water temperature, conductivity (CTD sensor) and corrected current profile (ADCP) at AUV altitude
- Valuable early information for sub-sea work plan & designing application

**Water Temperature Gradient Map**

**ADCP Current Vector Stick Horizontal Chart**
AUV Survey for Unconventional Application
AUV Magnetometer – UXO Survey

- Doubling of altitude decrease magnetic signal strength by a factor of eight
- Very low altitude (around 5 meters) will be required to detect UXO type objects
- High quality positioning (<2 meters grid line spacing) is a must for small UXO surveys

=> AUV providing an ideal platform

- Magneotmeter should be small enough to integrate on AUV
- AUV must record propulsion & rudder control amperage draw for use during post processing.
- Sensor calibration should be conducted at an AUV high altitude in a gradient free area. Suitable locations to be located via Fugro Airborne data.
- Potential application for sub-sea mining, debris survey, pipeline & cable detection in deep water
Micro-Gravimeter on AUV

- Very detailed high accuracy measurement for microgravity investigation
- Specific interest from deep ocean mining application
- Potential application for deep sea oil and gas exploration – shallow targets identification

- AUV is considered a promising platform
  - high accurate and reliable position and height of sensor
  - High resolution multibeam data of seabed topography
AUV for IRM Survey

- Acoustic inspection by side scan sonar, two options:
  - Conventional high frequency SSS (300/600/1600kHz) arrays:
  - 600kHz resolution Cross track 1.5cm, along track 15cm @ 25m range;
  - Or
  - SAS (Synthetic Aperture Sonar) Resolution 5 x 5cm
AUV for IRM Survey

- Optical inspection by digital stills:
  - Camera plus LED lamp;
  - Overlapping tiles to form mosaic.

Data from TileCam still image camera

Altitude 4.6 m
Resolution 2.3x2.3 mm

Recorded Wednesday

Recorded yesterday
The Platform Inspection mission profile involves successive passes around the platform at a 15m standoff, with 50% overlap of 3D sonar scans between passes.
Platform Inspection Data Deliverables
Summary

• AUV offers a stable and reliable platforms that expands the dynamic of geophysical survey
• New and innovative applications are being introduced, and explored
• Revolution in the survey industry is anticipated
Thank you!!

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