Subsea Fiber-Optic Sensing Applications: How To Make It Happen
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Enhancing Production Profiling with Fiber Optic Technology

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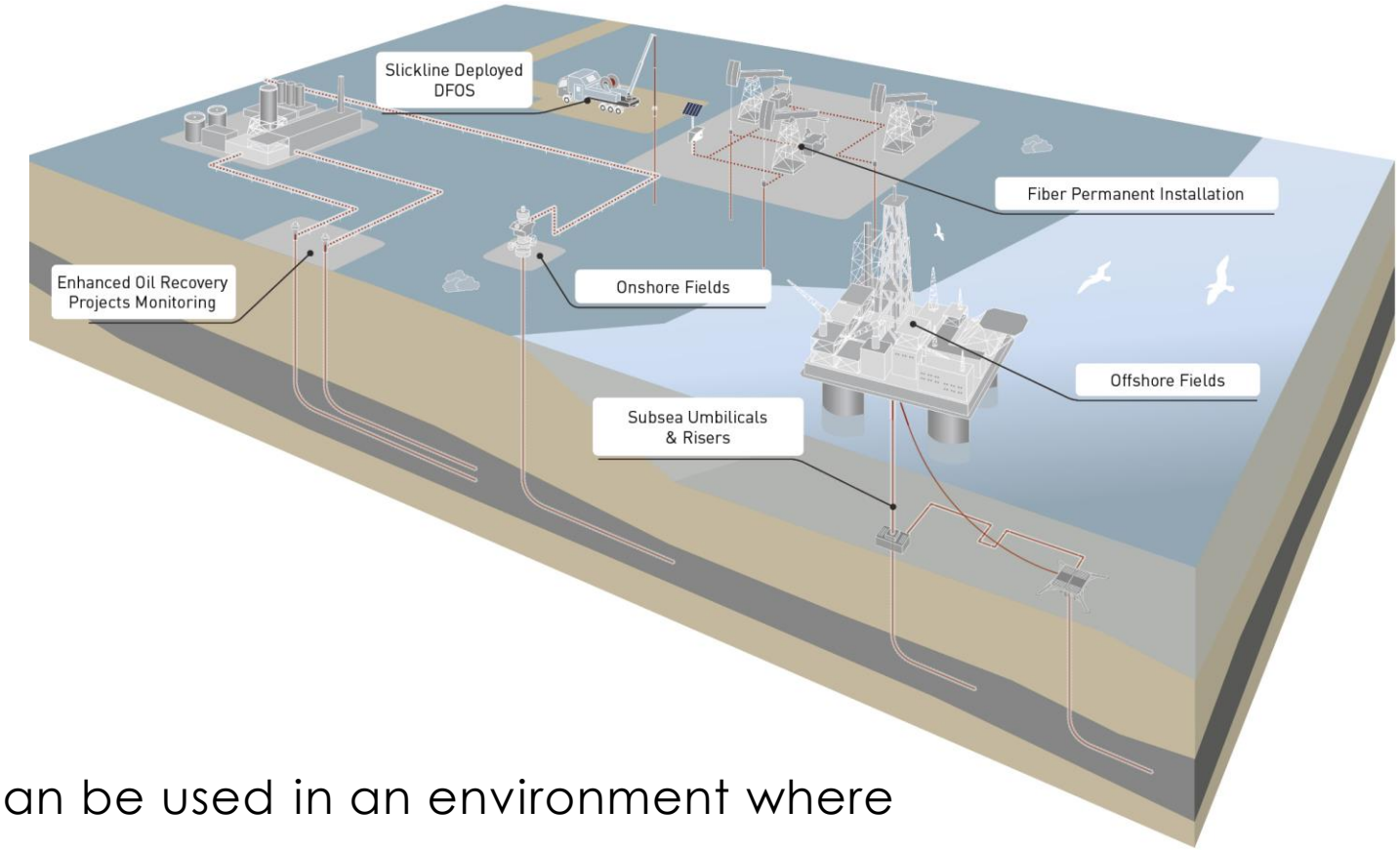
Agenda

- Introduction
- Production monitoring when conventional PLT tools can't be used
  - Case study 1: Onshore gas well
  - Case study 2: Offshore HT/HP gas well
- Conclusions

Introduction

- Various applications:
  - Well integrity monitoring
  - Hydraulic fracturing
  - Borehole seismic
  - Production profiling
  - ….



Objective

- To show that DFOS data can be used in an environment where conventional production logging is not possible.

Case Study 1. Production monitoring in a gas well **(SPE-216618)**

Background

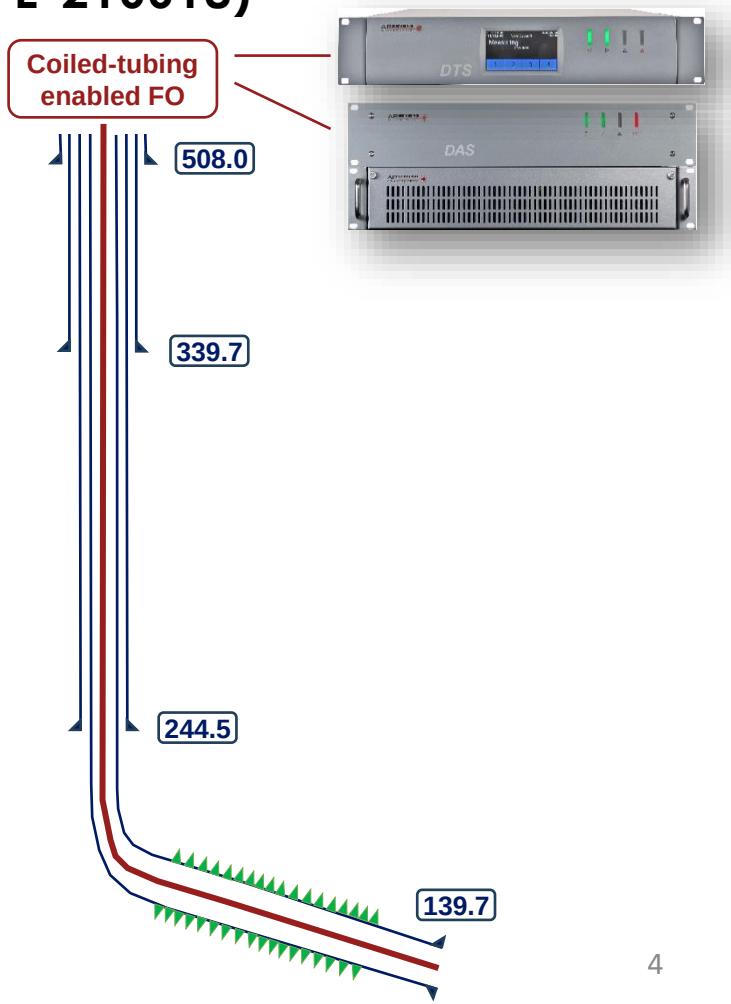
- China, onshore gas field
- Horizontal well, inclination ~90-92 deg
- Well TD ~ 5 km
- Horizontal section ~1.2 km

Challenge

- The Operator rejected use of conventional PLT tools

Solution

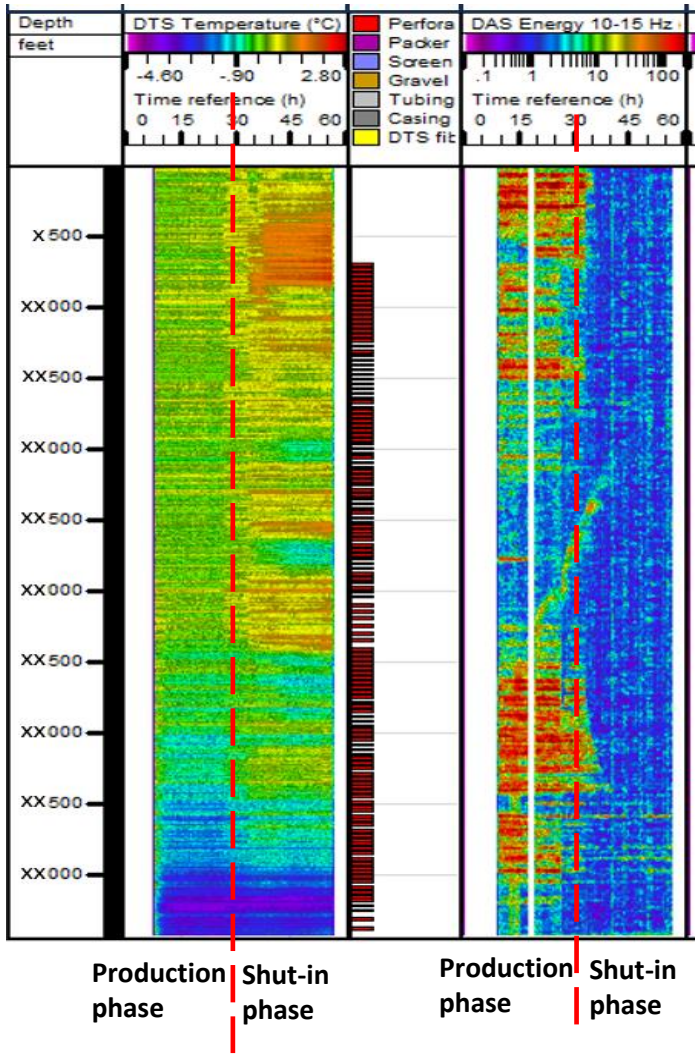
- Coiled tubing-enabled optical fibers
- ~50 hours of data acquired during different regimes

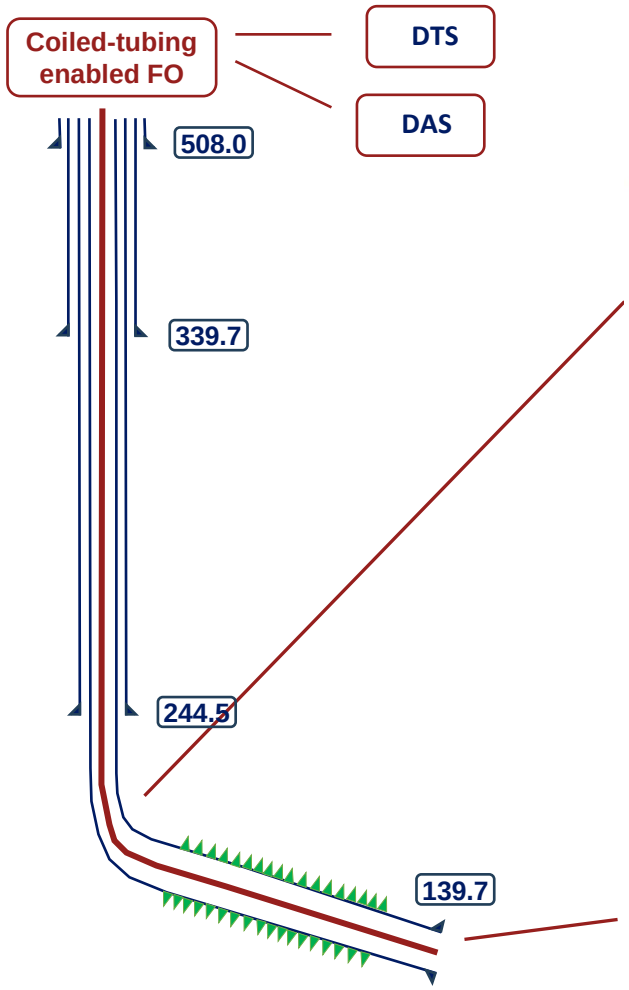


Job Execution

- FO-enabled coiled tubing, DTS and DAS data were acquired simultaneously

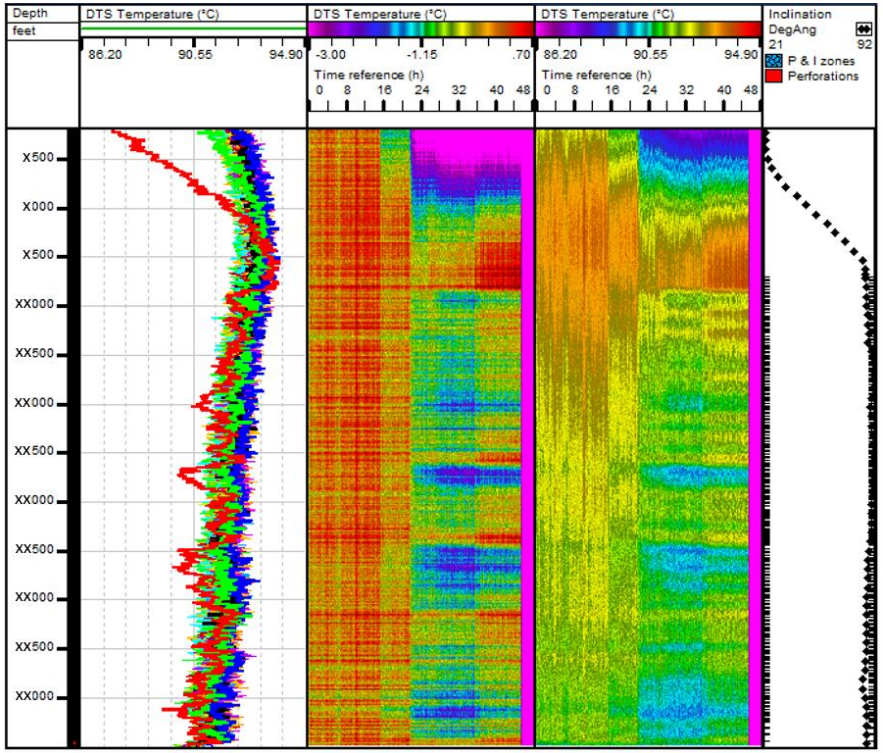
- ~50 hours of DTS and DAS survey during different regimes:
  - xx MMSCF/day flow rate 9 hrs
  - x MMSCF/day flow rate 7 hrs
  - x MMSCF/day flow rate 7 hrs
  - Shut-in



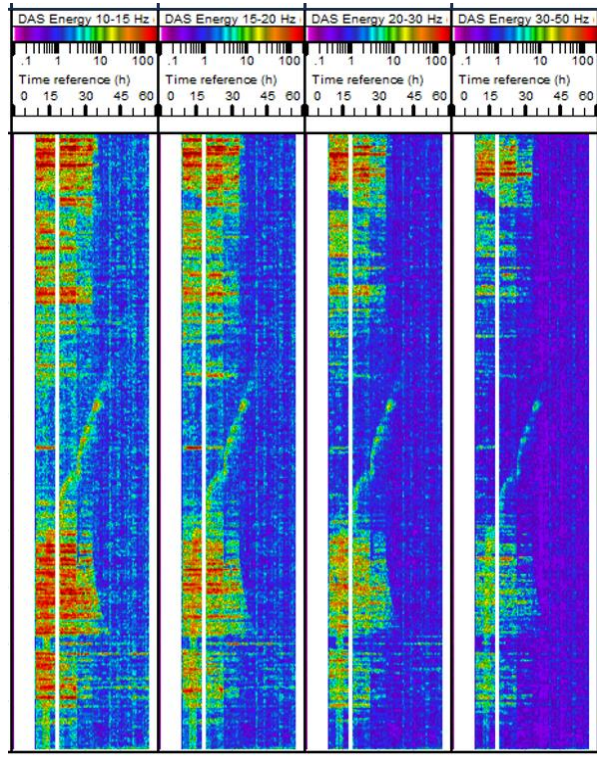


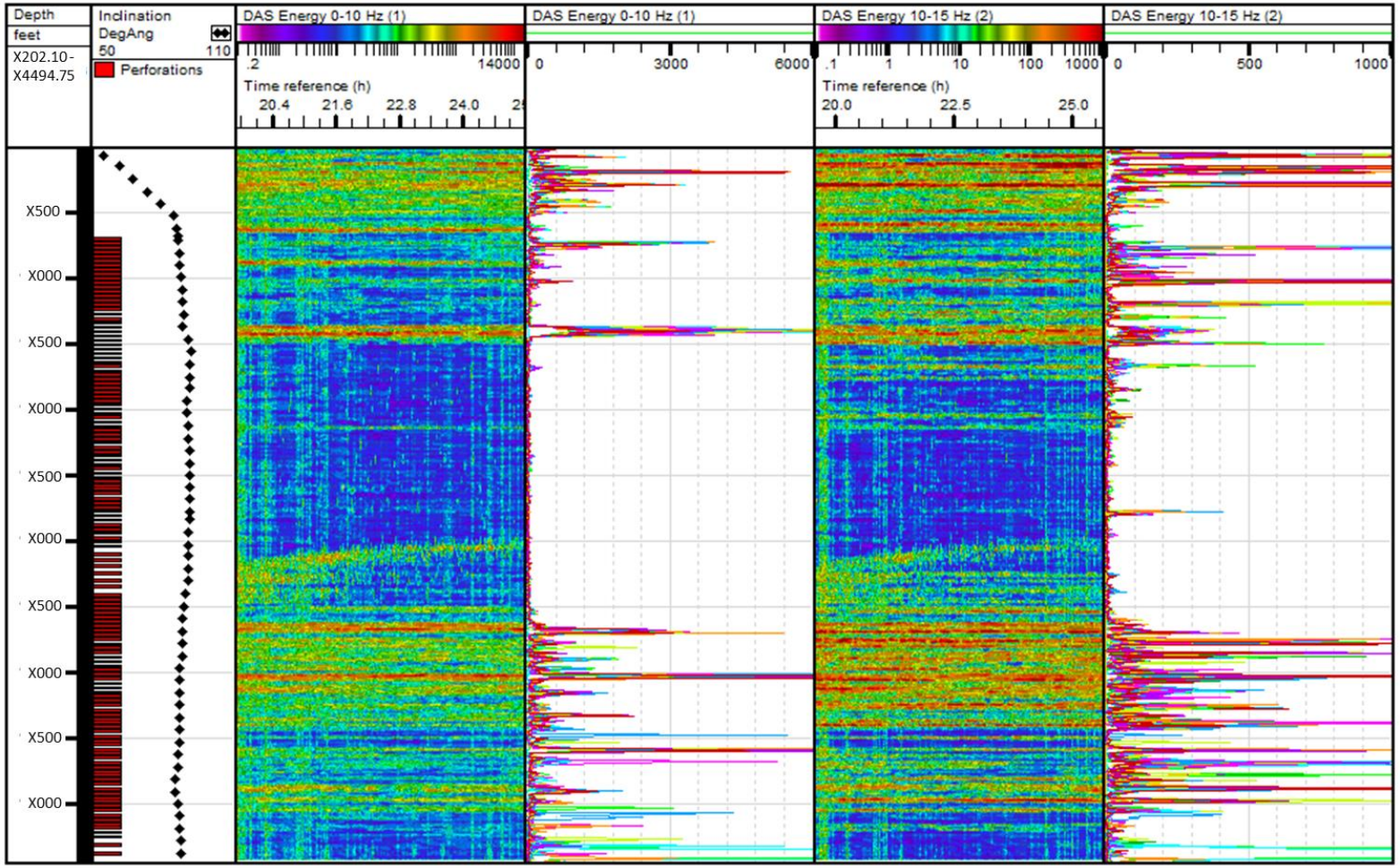
DFOS data in reservoir section (~50 hours)

Distributed Temperature Sensing



Distributed Acoustic Sensing





- DAS data in reservoir section
- DAS data allows qualitative identification of producing zones

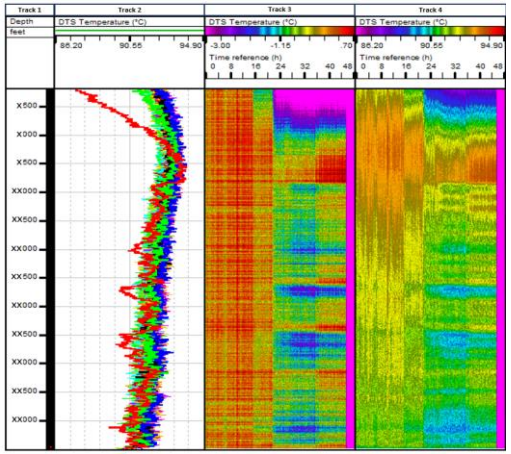
Stage	Perforation point (ft)	DAS Response
1	xx439	
	Xx370	
	Xx301	
2	Xx242	
	Xx209	v
	Xx177	v
	Xx145	
	Xx113	
	Xx080	
3	Xx042	v
	Xx009	
	Xx976	v
	Xx945	
	Xx912	
	Xx880	v
4	Xx842	
	Xx809	v
	Xx776	
	Xx745	v
	Xx712	
	Xx679	v
5	Xx642	v
	Xx609	
	Xx576	v
	Xx542	
	Xx509	
	Xx476	
6	Xx438	
	Xx406	v
	Xx373	v
	Xx342	
	Xx309	v
	Xx276	v
7	Xx238	v
	Xx205	
	Xx173	v
	Xx141	v
	Xx109	
	Xx076	
8	Xx038	v
	Xx005	v
	Xx972	v
	Xx941	v
	Xx908	
	Xx876	v
9	Xx838	v
	Xx805	v
	Xx772	v
	Xx738	

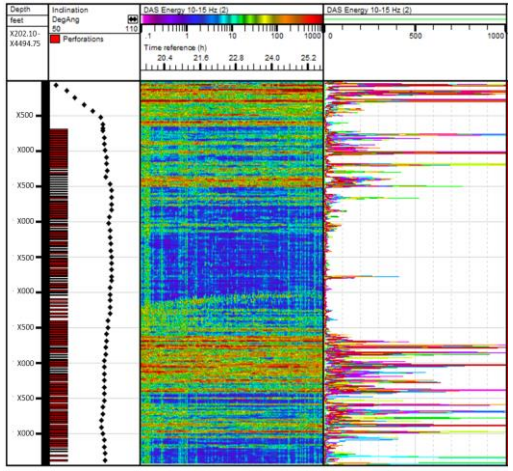
Stage	Perforation point (m)	DAS Response
	Xx705	v
	Xx672	
10	Xx635	v
	Xx602	
	Xx569	
	Xx538	v
	Xx505	v
	Xx472	
11	Xx434	
	Xx410	
	Xx387	
	Xx364	v
	Xx341	
	Xx318	
	Xx295	
	Xx272	
12	Xx234	v
	Xx210	
	Xx187	
	Xx164	
	Xx141	
	Xx118	
	Xx095	
	Xx072	
13	Xx034	
	Xx001	
	Xx969	
	Xx934	
	Xx901	
	Xx868	
14	Xx831	
	Xx798	
	Xx765	v
	Xx734	
	Xx701	
	Xx668	
15	Xx631	
	Xx599	
	Xx568	
	Xx537	v
	Xx506	
	Xx475	
16	Xx437	
	Xx406	
	Xx375	
	Xx344	
	Xx312	
	Xx281	
17	xx243	

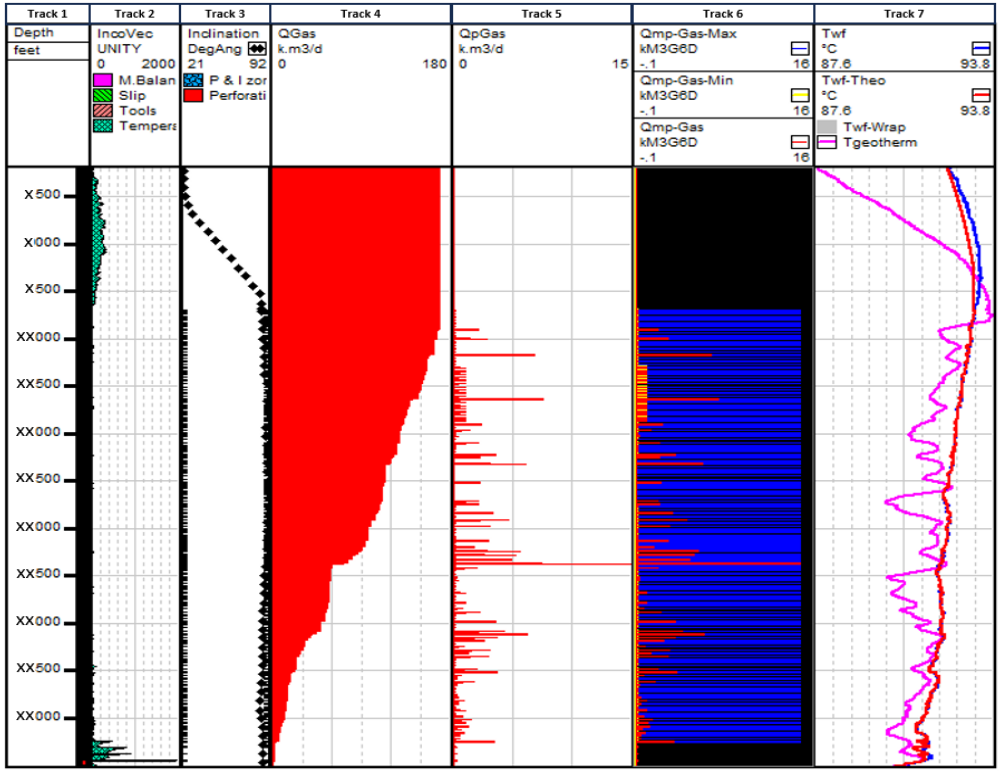
Stage	Perforation point (m)	DAS Response
	Xx212	v
	Xx181	v
	Xx150	
	Xx119	v
	Xx088	
18	Xx050	v
	Xx019	
	Xx988	
	Xx956	v
	Xx925	
	Xx894	
19	Xx856	v
	Xx825	
	Xx792	
	Xx761	v
	Xx728	
	Xx697	
20	Xx659	v
	Xx628	
	Xx595	v
	Xx564	
	Xx531	
	Xx500	v
21	Xx463	v
	Xx430	
	Xx397	v
	Xx366	v
	Xx333	v
	Xx300	v
22	Xx262	v
	Xx230	
	Xx197	v
	Xx162	v
	Xx130	
	Xx097	
23	Xx059	v
	Xx026	v
	Xx93	
	Xx62	v
	Xx29	v
	Xx97	v
24	Xx59	v
	Xx26	
	Xx93	v
	Xx59	v
	xx26	

- DAS data allows qualitative identification of producing zones

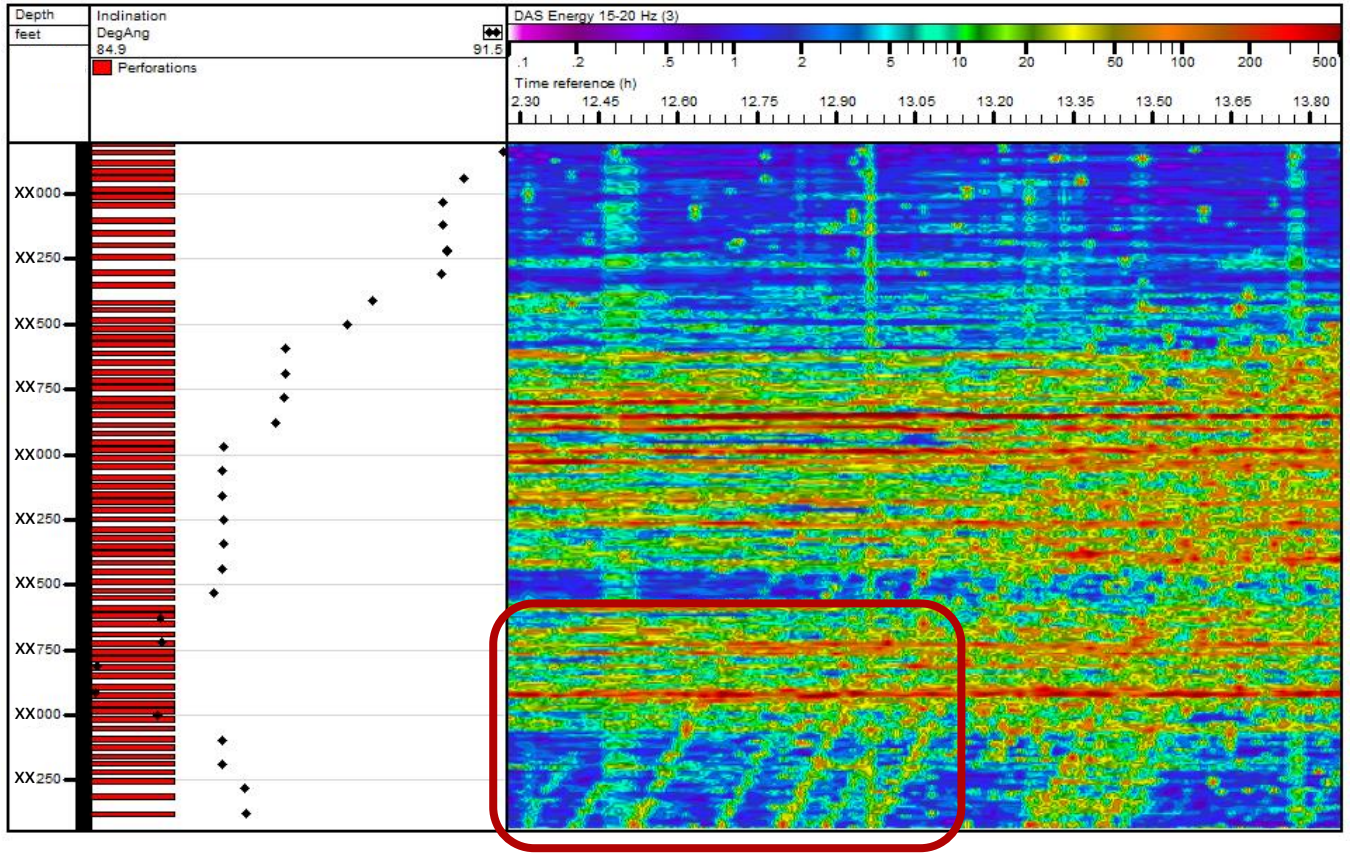
- For each perforation cluster the DAS response is verified

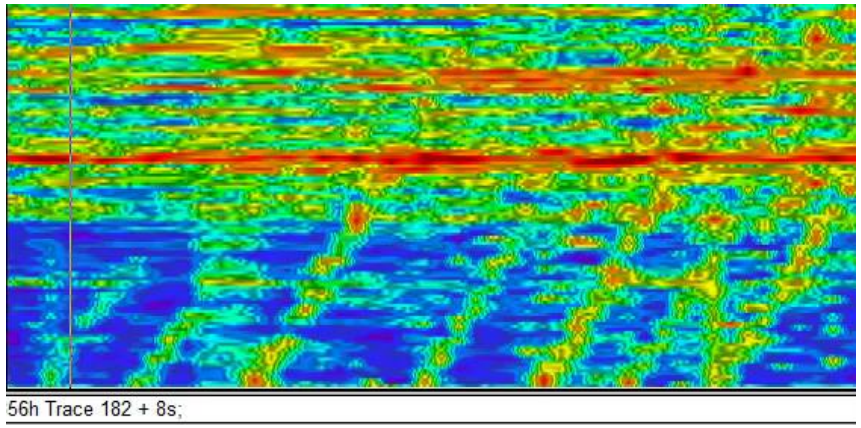






- DTS data preparation
- Identification of producing zones
- Flow rates computation
- Quantitative analysis of DTS data integrated with interpretation of DAS data.





- A small amount of fluids is observed flowing up from below the logged interval

- It is possible to obtain the velocities of this fluid movement

Case Study 1. Production monitoring **(SPE-216618)**

Summary:

- Risks related with utilizing of conventional PLT tools were mitigated by using CT with fiber optics

- DTS is a well-established tool for quantitative production profiling.

- To overcome potential limitations in DTS data analysis, combining DTS and DAS is suggested through post-processing interpretation software

Case Study 2. Production monitoring in a HTHP gas well **(SPE-215512)**

Background

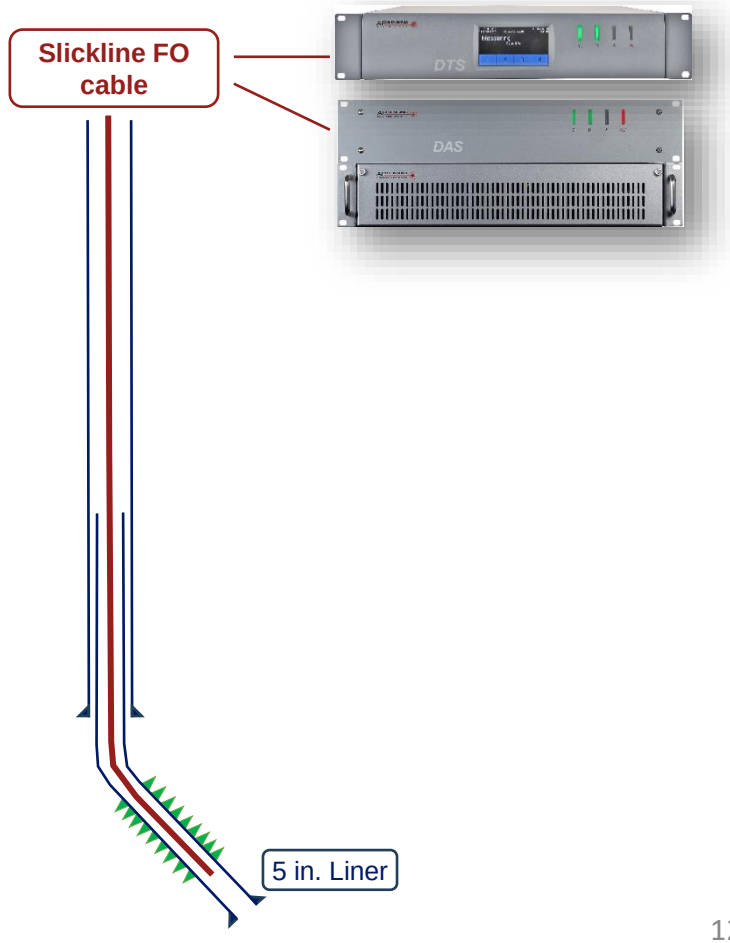
- North Sea, HP/HT gas field
- Deviated well, inclination ~40-45 deg
- Well TD ~ 5 km

Challenge

- Conventional PLT tools' ineffectiveness due to tar-like deposits in the tubing clogging the sensors and slickline tension constraints

Solution

- Slickline fiber optic cable



EXPRO

Technology Selection

- Culzean field in the Central North Sea
  - Initial reservoir pressure 936 bar
  - Temperature 176 deg C
  - Thin-layered deposits
  - Tar-liked deposits
  - High production rates

- Traditional production logs aborted due to clogged spinners from organic residue
- Increased risk of tool lift
- Unsuccessful PLT since the start of production over 3 years ago

Previous deployment attempt

Conventional PLT tool or Fiber Optic Line?

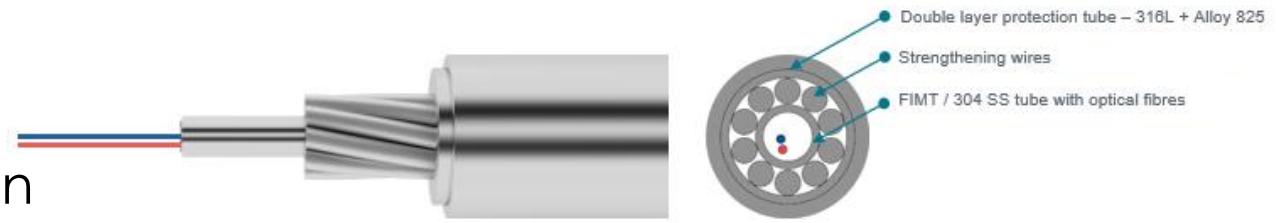
Surveillance option	Risk of clogging	Risk of tool string ejection	Flow rates	Cable rating	Cost
Conventional PLT toll string	High	High	Limited to 45 MMSCF/day	0.160" SL cable	Lowest cost
PLT tool string on FO line	High	Tools below perforation for flowing period	60 MMSCF/day	0.160" SL cable Not suitable	Medium
P&T gauges only on FO line	Low	Tools below perforation for flowing period	60 MMSCF/day	0.160" SL cable Not suitable	Low

Job Execution

- FO Slickline cable

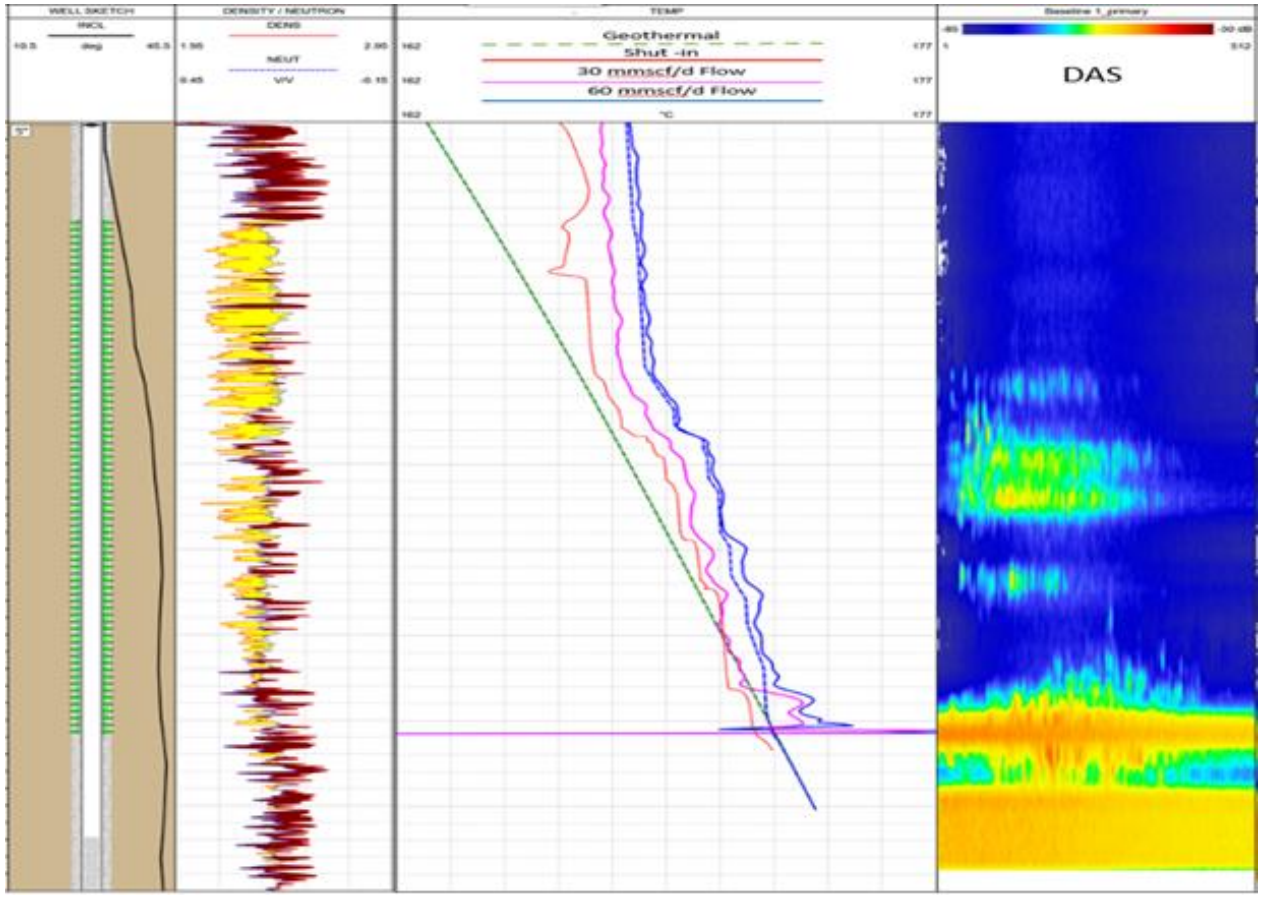
0.160 in cable was replaced by 0.181 in cable

- 20 hours of DTS and DAS survey during different regimes:
  - Shut-in Baseline 1.5 hrs
  - 30 MMSCF/day flow rate 9 hrs
  - 60 MMSCF/day flow rate 7.5 hrs
  - Post Flowing shut-in 2 hrs



- **High-Tension and High-Temperature DFOS Slickline**

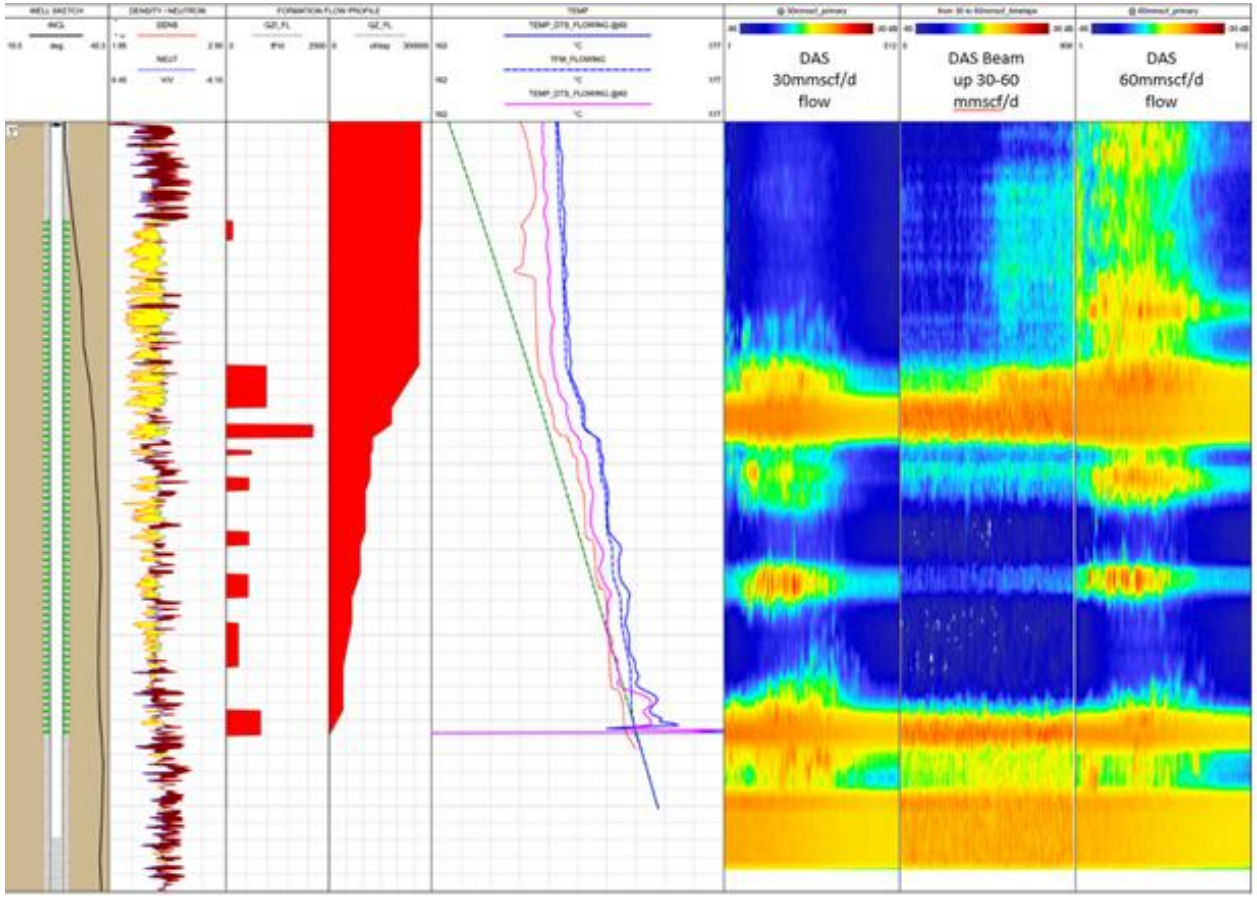
Job Execution



- DTS data for flow allocation for shut-in, 30 MMSCF/day and 60 MMSCF/day flow rates.

- DAS data during shut-in

Job Execution



- DTS thermal inversion performed to allocate relative flow volumes.

- DAS indicates changes in the flow contribution with flow rate

Case Study 2. Production monitoring in a HTHP gas well **(SPE-215512)**

Summary:

- By using slickline cable, risks associated with tool lift and wellbore debris were effectively mitigated, preventing the utilization of conventional PLT strings.

- Data from DAS and DTS were acquired in HT/HP well under multi-rate flowing conditions.

- First-ever Production Profile from this field under such conditions.

Conclusions

- FO emerges as a reliable alternative when conventional PLT tools are not feasible
- FO can be deployed using various methods (slickline, coiled-tubing...)
- Fiber Optic Sensing technology advantages include:
  - Mitigation of risks associated with conventional tools.
  - Monitoring the entire wellbore in various operational states.
  - Obtaining results immediately post-survey.
  - Contribution to more efficient reservoir management.

Acknowledgements

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Obrigada!

Thank you!