Denmark offshore – platform margin Licence 11/16 (Jarnsaxa Prospect)

Opportunity Summary

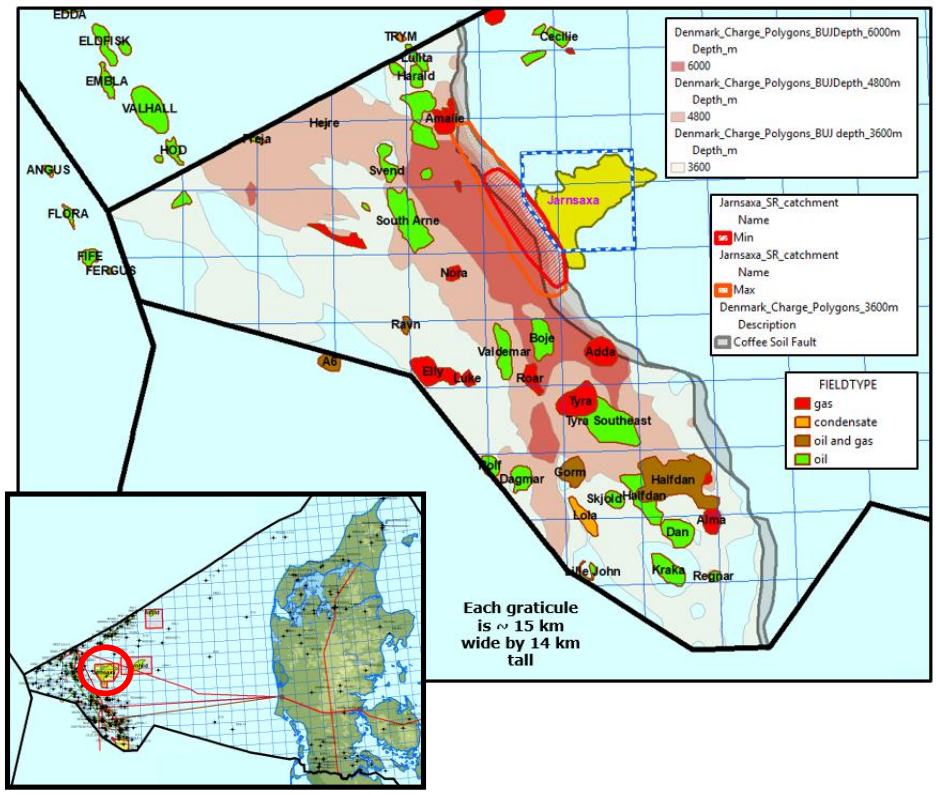
Licence 11/16 (426.5 km^2) was awarded to Ardent Oil in the 7th round of Danish Licensing. The licence, awarded 6th April 2016, is for a phased 6-year term. Acquisition of new 3D broadband in 2016 has allowed much better prospect definition than was previously possible, taking it to a drill-ready status. A very large, undrilled structure (Jarnsaxa Prospect) has been identified within the acreage and a 2019 exploration well (non-HPHT ~ 45 days 3500 m TD) has equity available for farminee participation. The reservoir objective is within fractured basement of likely Pre-Cambrian age. The depth to the crest of this structure is approximately 2575 m subsea and mean recoverable prospective resources for Jarnsaxa (90-100% on the licence) are estimated to be around 370 million barrels of oil. In place oil upsides are multi-billion barrel. The current licence holders are Ardent Oil Denmark, 80%, (operator) and Nordsøfonden, 20%.

Location map

Jarnsaxa location is shown at right with offset fields and extent of the main Danish Jurassic source kitchen (located in "Tail End Graben") which represents the southern termination of the North Sea Central Graben.

Note Jarnsaxa's optimal position for receiving a Jurassic charge from the basin depocentre.

The location relative to Denmark is shown in the inset.



Technical Information

Database. The 3D seismic database in the area consists of the PGS Broadband Geostreamer (323 km^2) and Danish Megasurvey (11,180 km^2) datasets along with further legacy 2D data. Well studies included all nearby wells, relevant source rock penetrations, and offshore Palaeozoic penetrations.

Reservoir: The Jarnsaxa basement unconformity has not been penetrated by wells in the vicinity. Basement penetrating offset wells are distant, with a variety of basement units from different tectonic units. However the nature of the host rock is considered less important than the clear development of intense faulting and fracturing within the Jarnsaxa basement due to multiple tectonic phases of contraction, strike-slip, and extension, newly visible on broadband data. For much of this history the prospect is likely to have been exposed subaerially, increasing the chance of fractured reservoir effectiveness.

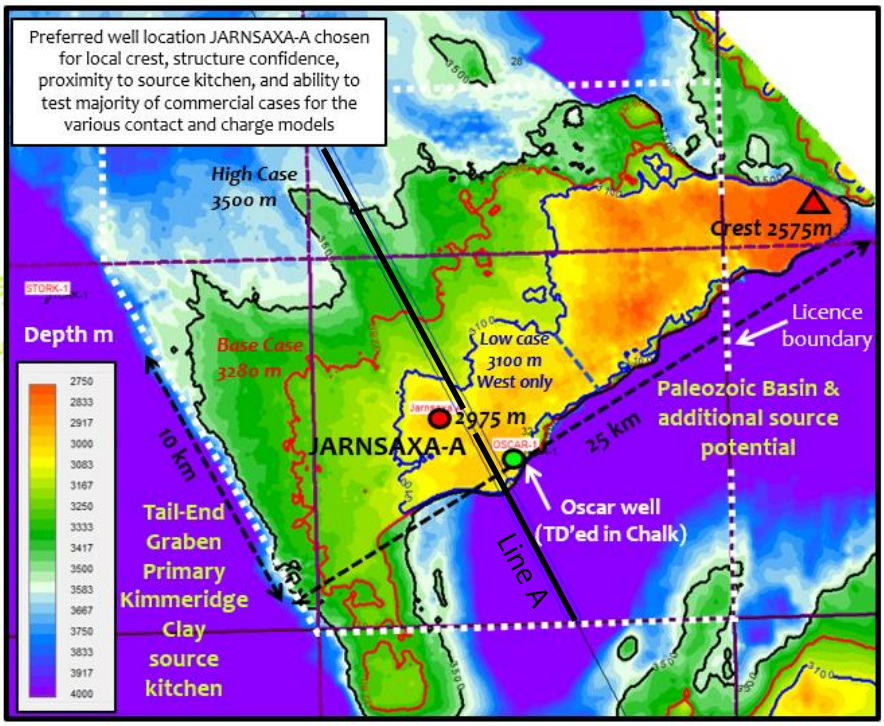
Structure. The Jarnsaxa structure is a complex thrust-fault bounded anticline cut by later faulting episodes. Mapping indicates about a km of vertical relief. It first evolved in early Paleozoic and earlier thrusting events, verging to the S and E. A phase of strike-slip and extensional faulting in the later Paleozoic to Triassic has accentuated the structure. Late Jurassic extension along the Tail-End Graben provides dramatic km-scale normal faulting closure to the west, and associated faults cut and exploit Jarnsaxa's prior structures, and facilitate migration into the structure. Late Cretaceous and Tertiary inversion events have do not appear to have affected the structural integrity of the Jarnsaxa area.

Seal. The basement closure is sealed over most of its extent by Palaeozoic aged sediments, most likely to be Permian in age, and from the nearest offset well penetrations these are tight clastics and volcaniclastics. Overlying these is a complete sequence of Late Cretaceous pelagic chalk, which directly overlies basement in parts of the prospect. They are typically tight and form good seals in North Sea fields such as Auk. The well known chalk-reservoired fields in Denmark occur in the higher more porous chalk units and do not touch down to threaten Jarnsaxa seal. Offset well pressure data demonstrate at least 3000 psi of sub-regional pressure seal provided by the chalk, and the potential to retain the structure's maximum relief hydrocarbon column.

Source. Late Jurassic Kimmeridge Clay (equivalent) source rock in the Tail End Graben charges a large number of producing fields. It has been penetrated by the nearby Stork-1 well close to the prospect and mature source rock is directly placed against the fault systems bounding Jarnsaxa structure. It is possible that a deep Palaeozoic basin to the south of Jarnsaxa could provide additional charge from Carboniferous and older sources, but Ardent's evaluation and risking assumes solely Upper Jurassic source and migration.

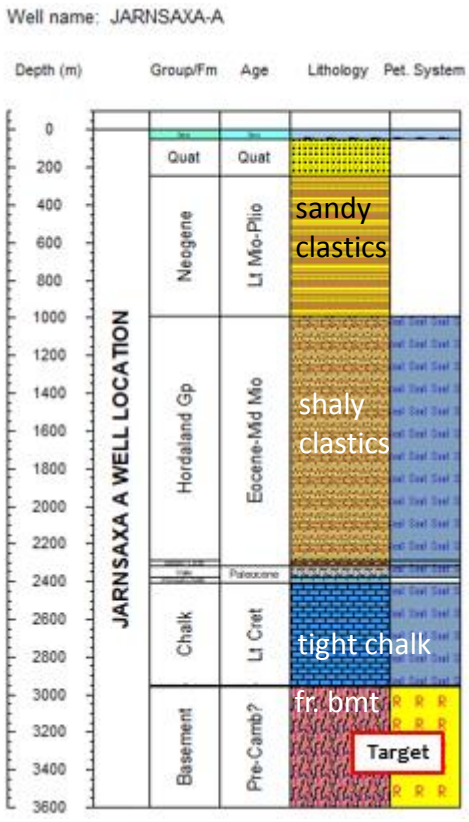
Production rates: These are a critical aspect of fractured basement reservoirs The exploration well will penetrate at least 500m of basement reservoir with a full suite of specialist tools to adequately test fractured reservoir. Long term testing will occur in the success case.

Jarnsaxa Prospect: Basement depth

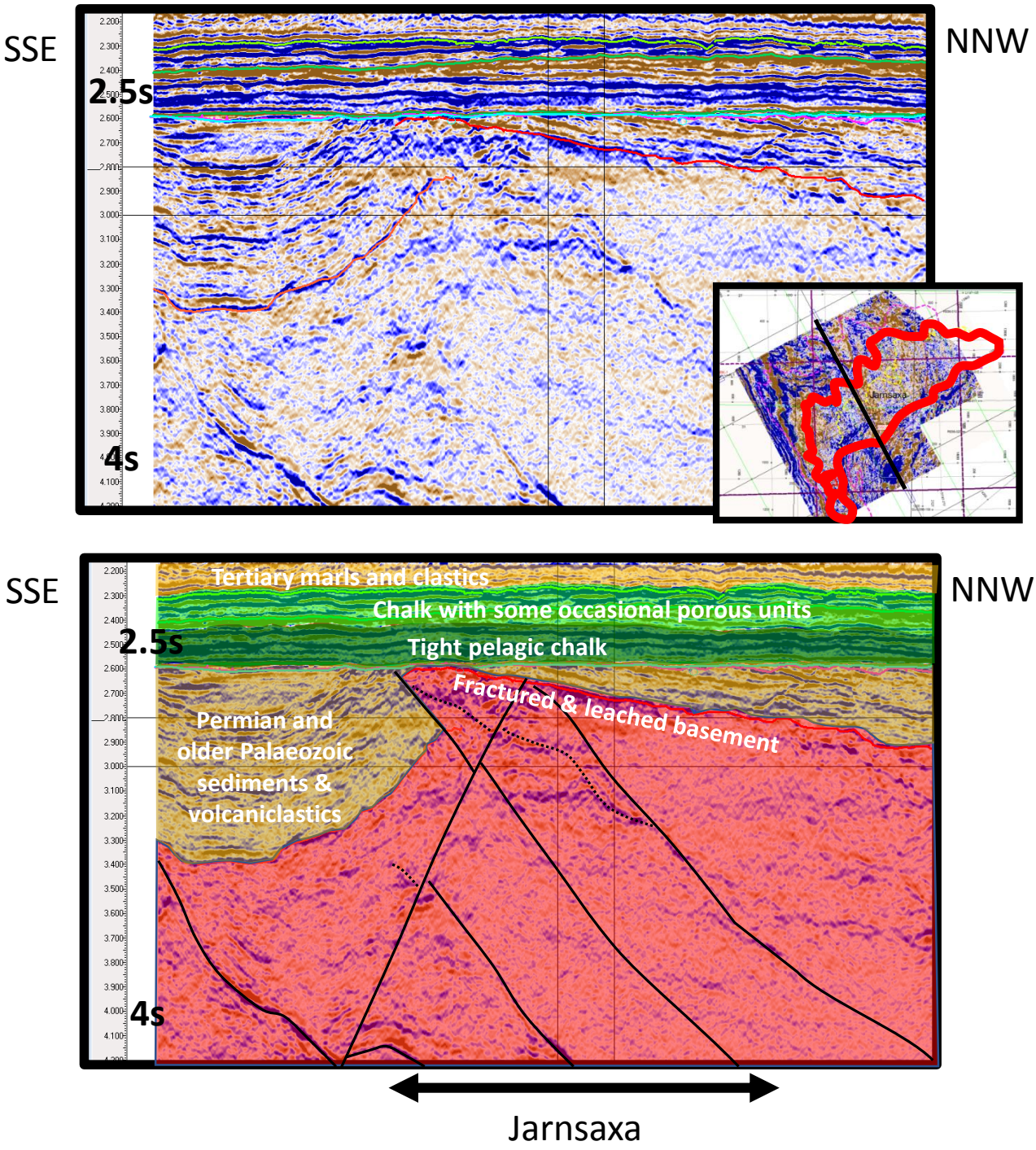


The NNW-SSE Section Line A is shown overleaf

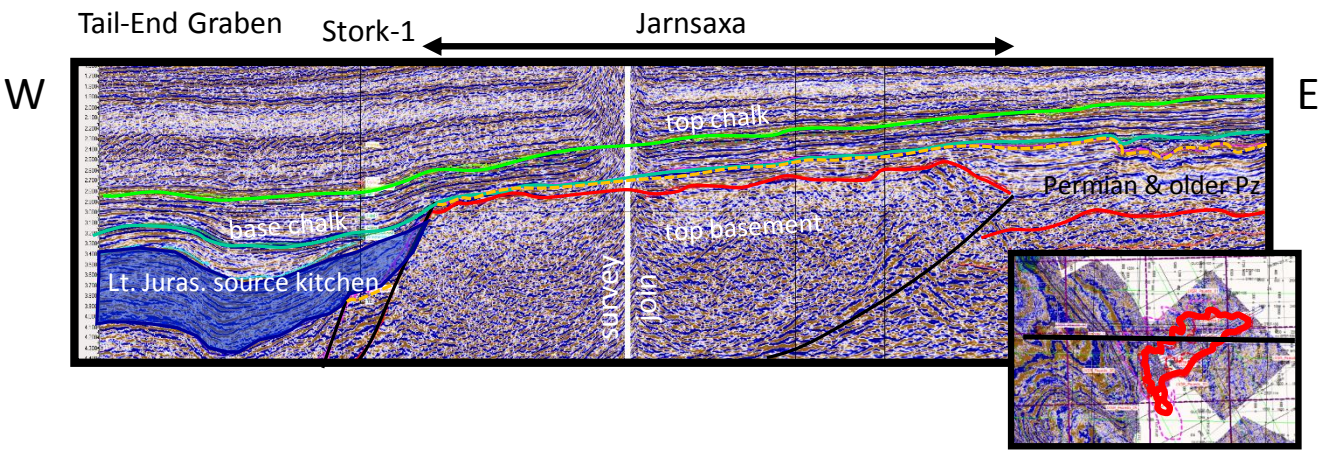
Stratigraphy



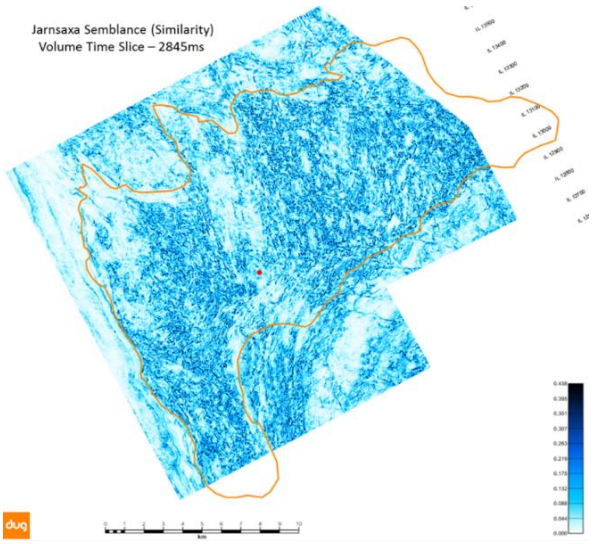
Jarnsaxa Prospect: Broadband seismic & geoseismic line A



Jarnsaxa Prospect: Megasurvey seismic line B



Fractured basement attribute studies



Seal & Charge analogue Auk Field

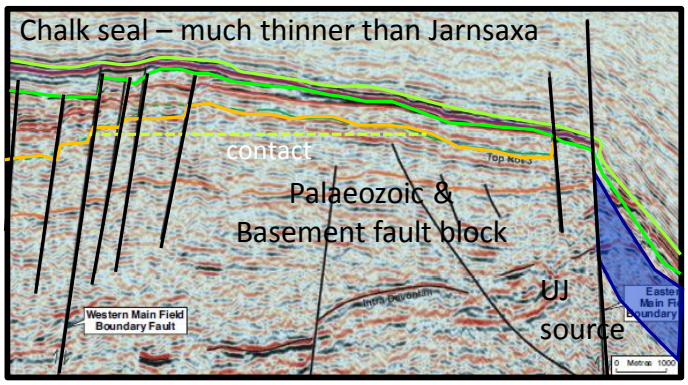


Image modified from Millennium Atlas (2003)

Analogue fields and pressure data analysis give encouragement for charge and chalk-sealing assumptions, and fracture attributes provide encouragement for reservoir quality.

Jarnsaxa Prospect (Variable Contact) Prospective resources

OIL CASE	STOIIP mmbbl	Rec Oil mmbbl	Rec Assoc Gas bcf	Rec Res mmboe
P90	146	28	11	30
P50	739	157	61	167
Mean	1582	370	148	394
P10	3712	848	340	904

Resource estimates assume an oil case with 90% probability. They allocate the structural closure volume at top basement (GRV) zones of highly, moderately, and poorly fractured reservoir, in line with literature from analogue fields. Prospect GRV is an *order of magnitude larger* than analogues such as Lancaster Field West of Shetland, but fracture porosity assumptions, reviewed by external experts, are more cautious given the undrilled status. Deterministic volumes at the proposed well location suggest lower end cases of 125-150 mmbbl STOIIP. Fractured basement analogues (e.g. Yemen) suggest individual well production rates of 4000-15000 bopd are achievable. Carefully managed development strategies are assisting success in the fracture basement globally.

Risks

The overall risk for Jarnsaxa is currently estimated at 23%. The main risk factors are fractured basement reservoir effectiveness and seal of overlying Late Cretaceous chalk and Permian volcaniclastics. The quality of broadband imaging over the structure lends itself to further de-risking as the extent and distribution of fracture zones are more precisely delineated.

Licence Details

Effective date: 6th April 2016, duration:6 years.

Work programme and phasing:

Years 1-3:	Data reprocessing and technical studies. Drill or drop decision April year 3. Drill one exploration well to evaluate Pre-Cambrian basement.
Years 4-5:	Commit to a 2nd exploration well or relinquish (except for any area justifiably retained for appraisal in the event of a year 3 drilling success).
Years 6:	Drill second exploration well.