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The Jansz-Io Gas Field, Northwest Shelf Australia: A Giant Stratigraphic Trap

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ABSTRACT

The Jansz-Io gas field is located in production licenses WA-36-L, WA-39-L, and WA-40-L within the Carnarvon Basin, northwest shelf, Australia. It is 70 km (43 mi) northwest of the Gorgon gas field, 140 km (87 mi) northwest of Barrow Island, and 250 km (155 mi) from Dampier on the northwest coast of Western Australia. Water depths vary from 1200 to 1400 m (3937 to 4593 ft) across the field.

The Jansz-Io gas field was discovered in 2000 by the Jansz-1 exploration well. A three-dimensional (3-D) seismic survey was acquired in 2004, and a further five wells were drilled between 2000 and 2009 to further delineate the field extent and size and characterize the resource to facilitate progress toward development.

The Jansz-Io hydrocarbon trap extends over 2000 km^2 (772 mi^2) with both structural (faulted anticline) and stratigraphic (reservoir pinch-out) components. The stratigraphic component of the trap is defined by the reservoir extent, which is limited by depositional downlap to the northwest, and erosional truncation by Upper Jurassic and Lower Cretaceous unconformities to the southeast.

The reservoir comprises muddy, bioturbated, predominantly very fine- to fine-grained sandstones deposited in a shallow-marine environment and is divided into two units. The upper wedge reservoir has 25 to 35% total porosity with 10 to 1000 md permeability, and the lower wedge reservoir has 15 to 25% porosity with 0.01 to 10 md permeability. Both reservoir units are expected to contribute gas during production.

The original gas in place (OGIP) for the Jansz-Io Oxfordian reservoir has a probabilistic range from 320 to 946 Gm^3 (11 to 33 tcf), with a P50 value of 632 Gm^3 (22 tcf). The ultimate recovered gas for the field will depend on both the development plan and the reservoir performance over field life. For the current 15-well development plan, the resource estimates range from 201 to 442 Gm^3 (7 to 16 tcf).

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The Jansz-Io gas field is a key part of the greater Gorgon liquified natural gas (LNG) project and will supply gas to the LNG plant that is being constructed on Barrow Island. The development concept includes subsea completions from three drill centers placed on the seafloor connected to a subsea production pipeline to carry gas to the LNG processing plant.

For the first stage of field development, 10 development wells were successfully drilled and completed during 2012 and 2014. The second drilling campaign is planned to commence after field start-up with the timing dependant on field performance.

INTRODUCTION

The Jansz-Io gas field is located in production licenses WA-36-L, WA-39-L, and WA-40-L within the offshore Carnarvon Basin of Western Australia. It is 70 km (43 mi) northwest of the Gorgon gas field, 140 km (87 mi) northwest of Barrow Island, and 250 km (155 mi) from Dampier on the northwest coast of Western Australia. Water depths vary from 1200 to 1400 m (3937 to 4593 ft) across the field (Figure 1).

The recent discovery of this giant gas field, in a basin considered to be mature from an exploration perspective, has challenged explorers to reconsider exploration strategies in mature basins. The Jansz-Io gas field has a number of geological features that distinguish it from more conventional gas fields in the Carnarvon Basin and, indeed, from many other producing fields around the world. Jansz-Io is a giant gas field in a structural/stratigraphic trap, with a large areal extent and variation across the field from distal lower-shoreface to offshore transition facies (Jenkins et al., 2008, preceding sentences with SPE permission).

The Jansz-Io hydrocarbon trap extends over 2000 km^2 (772 mi^2) with both structural (faulted anticline) and stratigraphic (reservoir pinch-out) components. The structural component of the trap is defined by a northwest–southeast trending faulted anticline (Figure 2). The stratigraphic

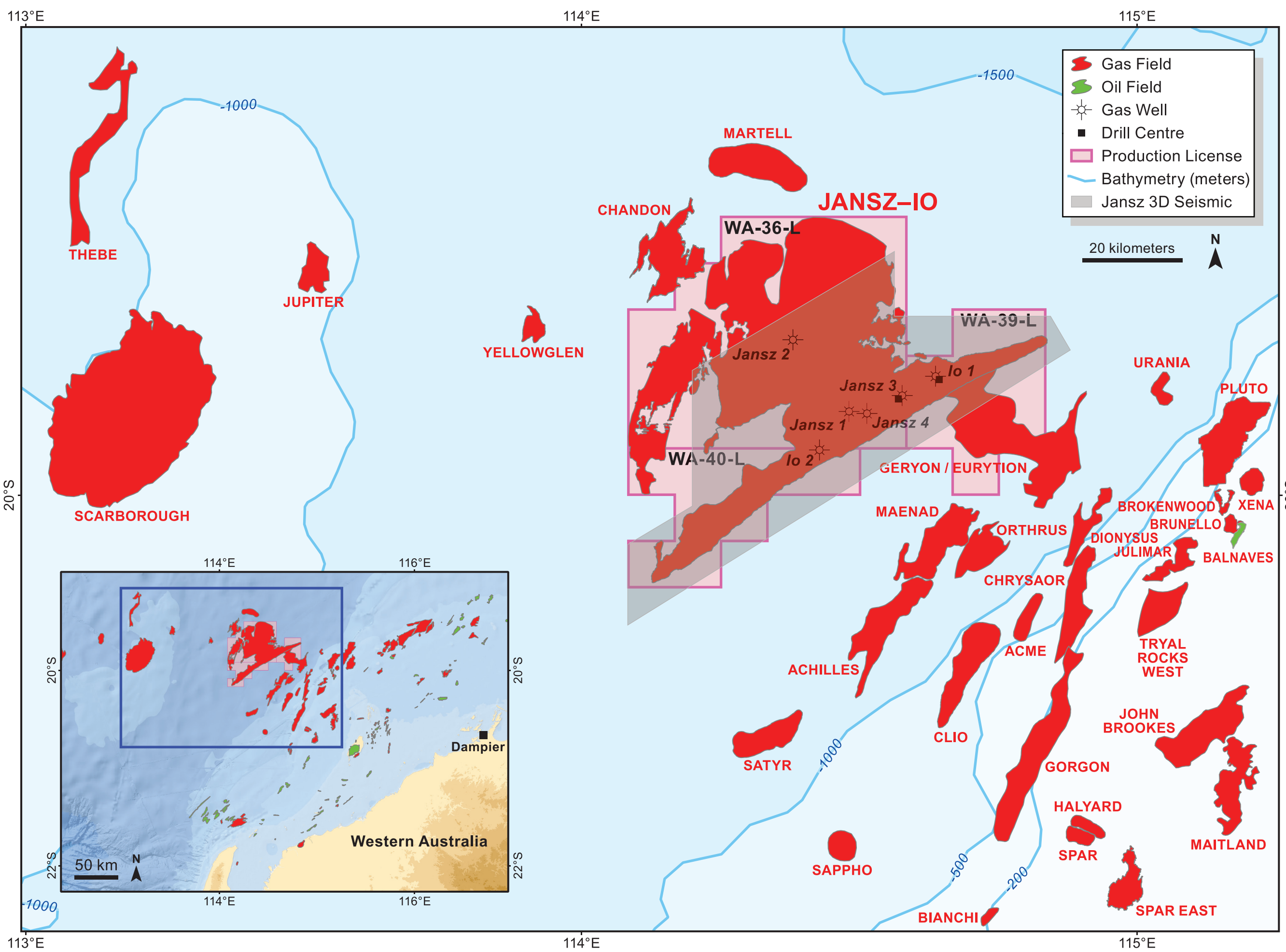

Figure 1. Jansz-Io gas field location. Includes data supplied by IHS, its affiliates and subsidiary companies, and its data partners. Copyright (2015), all rights reserved.

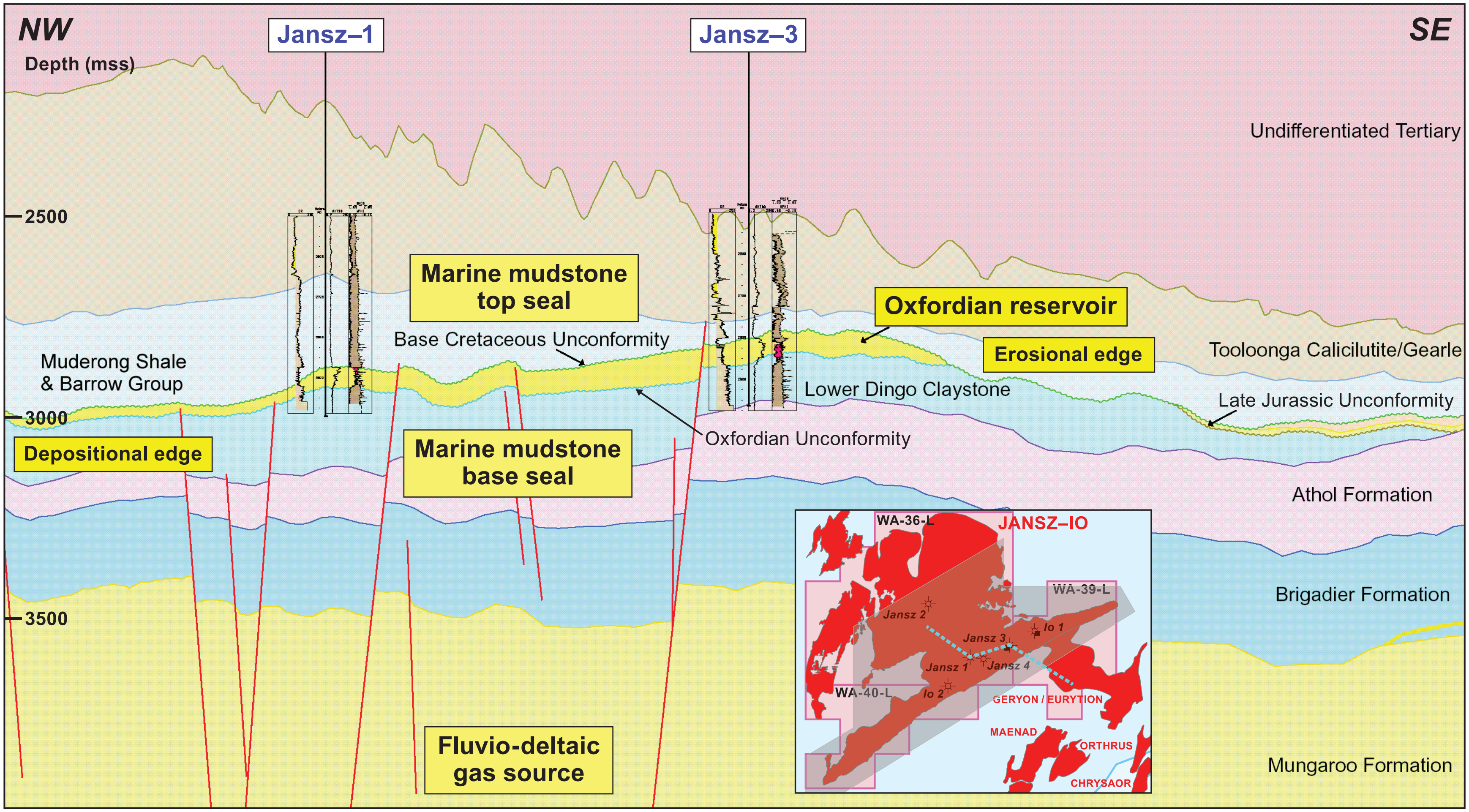

Figure 2. Hydrocarbon play schematic (after Jenkins et al., 2008, with permission from SPE, whose permission is required for further use).

component of the trap is defined by the reservoir extent, which is limited by depositional downlap to the northwest and erosional truncation by Upper Jurassic and Lower Cretaceous unconformities to the southeast.

The Jansz-Io reservoir is Upper Jurassic age (Oxfordian) and was deposited in a shallow-marine environment (Figure 3). While there are many hydrocarbon fields worldwide with reservoirs in a shallow-marine depositional setting, the difference between these fields and Jansz-Io is that the others usually contain hydrocarbons in high-quality, clean sandstones from upper-shoreface and lower-shoreface facies. By contrast, mud-rich offshore facies are the primary reservoir at Jansz-Io, whereas these deposits have low quality and typically have limited to no production in other fields (Jenkins et al., 2008, preceding sentences with SPE permission).

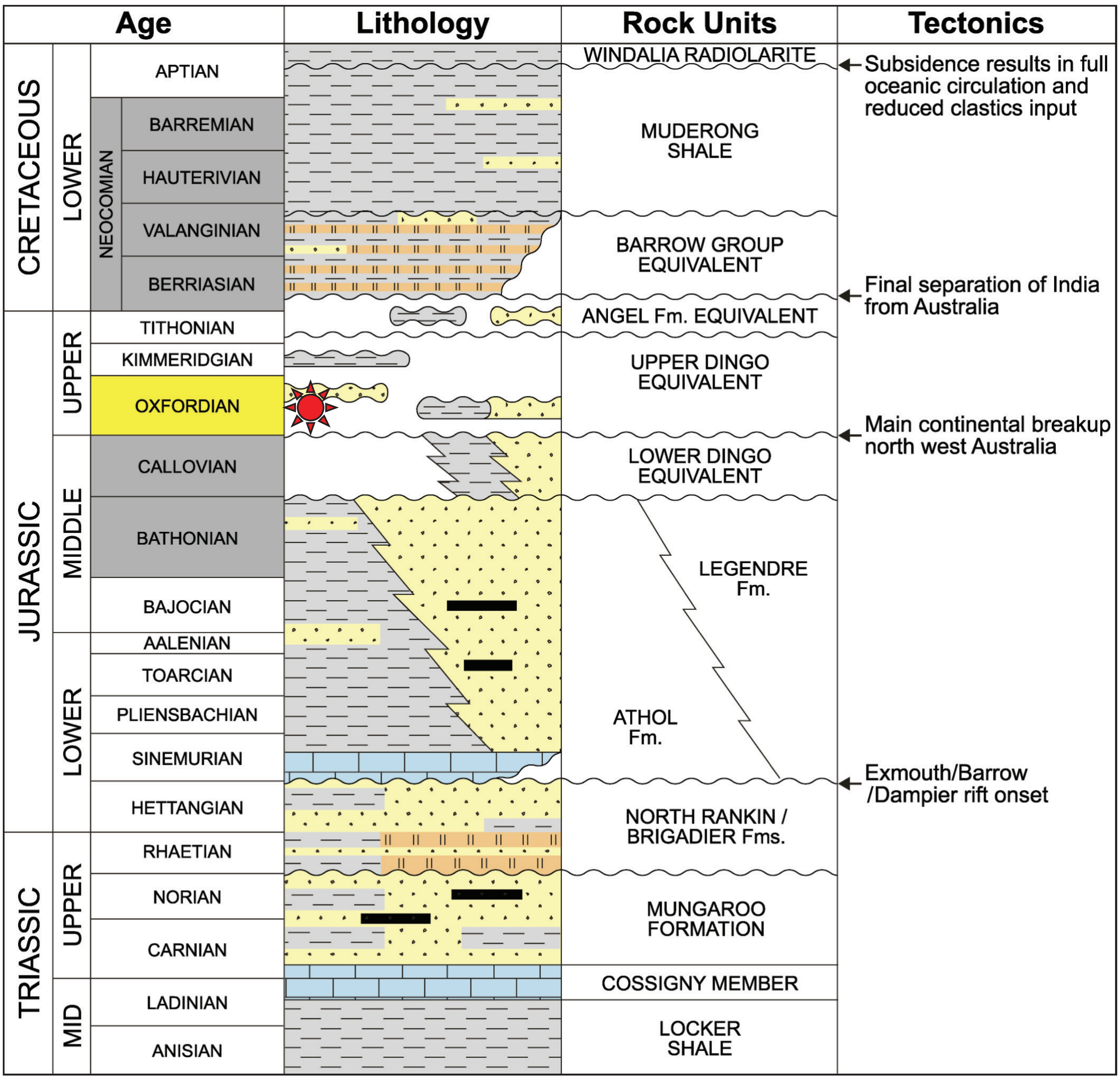

Figure 3. Carnarvon Basin Mesozoic stratigraphy (from Jenkins et al., 2008, with permission from SPE, whose permission is required for further use). The red gas symbol represents the stratigraphic interval for the Jansz-Io gas field.

The reservoir interval was first identified on 2-D seismic data with an apparent direct hydrocarbon indicator (DHI) response. This was confirmed after the discovery well was drilled and a high-quality 3-D survey was acquired. The reservoir unit is mappable on high-quality seismic data and is informally subdivided into the high-quality upper wedge and low-quality lower wedge reservoir units. The separation of these stratigraphic units is based on a seismically defined event designated the base of high permeability seismic marker (Figure 4). The top of porosity seismic marker defines the top of the upper wedge reservoir, and the Oxfordian unconformity marker defines the base of the lower wedge reservoir.

The marine mudstones of the Lower Cretaceous Barrow group and Middle Jurassic lower Dingo equivalent provide the top-seal and base-seal to the reservoir, respectively (Figure 2). The gas source is interpreted to be in the underlying deep gas-mature fluvial-deltaic section of the Upper Triassic Mungaroo Formation (Figure 3). The Jansz-Io gas composition exhibits a high methane content (89 to 94 mol%), with a low condensate yield of 25 m^3/Mm^3 (4.4 bbl /MMSCF) and a low CO_2 content (0.1 to 0.3 mol%).

The Jansz-Io play type contrasts with the nearby gas discoveries at Geryon-1, Urania-1, Orthrus-1, and Maenad-1A (Figure 1), which are fault-dependent structural traps, with gas-bearing sandstones in the fluvial-deltaic reservoir section (Figure 3) of the Mungaroo Formation (Korn et al., 2003).

Jansz-Io is a foundation field for the greater Gorgon LNG project; the other foundation field being Gorgon gas field located 70 km (43 mi) to the southeast. The project is a focus for development activity to meet an expanding global LNG market. The initial development at Jansz-Io has 10 high-angle wells drilled from two drill centers, DC-1 (five wells) located near Jansz-3 and DC-2 (five wells) located near Io-1 (Figure 5).

EXPLORATION HISTORY

The Jansz prospect was delineated with a 3 km $\times$ 1.5 km (1.9 $\times$ 0.9 mi) line spacing, 2-D seismic grid (Zeus survey), recorded during 1997, and the Jansz-1 discovery well was drilled in 2000 (Figure 1). A second well, Io-1, was drilled during 2001 some 10 km (6 mi) to the northeast of Jansz-1 and intersected the same Oxfordian gas reservoir updip of the discovery well (Jenkins et al., 2003).

The Zeus survey was reprocessed (in part) during 2001 and 2002, prior to the drilling of the Jansz-2 and Jansz-3 appraisal wells in 2002 and 2003, respectively. The Jansz-2 appraisal well demonstrated the lateral extent of the Oxfordian gas reservoir albeit in a more distal depositional setting. The well also confirmed the use of seismic amplitude versus offset analyses to delineate the field edges (Figure 6). The gas sandstones generally exhibit a prominent far-offset, Class 3 amplitude anomaly according to the classification scheme of Rutherford and Williams (1989). The Jansz-3 appraisal well was located in the core area of the field near the crest of the Jansz-Io structure and produced gas to surface from the cased-hole production test (Figure 4), confirming reservoir deliverability.

The 2892 km^2 (1117 mi^2) Jansz 3-D seismic survey was acquired during 2004 over the core area of Jansz-Io and part of the northern extension of the field (Jansz-2 area), with pre-stack time-migrated processing completed during 2005 (Figure 1). The 2-D and 3-D interpretation has been fully integrated and provides seismic coverage of the Oxfordian gas reservoir. The quality of the 3-D image in the primary development area was improved by anisotropic pre-stack depth migration (APSDM), with a minicube processed during 2006, and the entire seismic volume was reprocessed in 2012.

The Io-2 appraisal well was drilled during 2006 and deepened the lowest known gas (LKG) for the field from –2883 meters subsea (mSS) (–9459 ftSS) in the Jansz-1 well to –2970 mSS (–9744 ftSS). The well indicated that compaction (caused by greater depth of burial) and diagenesis had affected the reservoir quality in the southwest part of the field.

The Jansz-4 appraisal well was drilled during 2009 to confirm the location of the third drill center for the development. The first two drill centers are located near the Jansz-3 and Io-1 appraisal wells. The Jansz-4 well confirmed high-quality gas-bearing sandstones in the upper wedge reservoir and flowed gas to surface during a cased-hole production test of this zone (Figure 4). Dual-packer wireline modular formation dynamics tester (MDT) tests were conducted in low-permeability sandstones of the lower wedge, confirming moveable gas in this zone.

Six exploration/appraisal wells were drilled in the Jansz-Io gas field prior to development, with 260 m (853 ft) of full-hole core cut within the reservoir. All of the wells have comprehensive wireline log suites, including vertical seismic profiling at Io-1, Io-2, Jansz-2, and Jansz-4 and magnetic resonance logs in all wells except Jansz-1.

For the first phase of the Jansz-Io development, 10 wells were successfully drilled at 80° through the reservoir and completed between 2012 and 2014. These wells were fully evaluated using logging while drilling (LWD) technology.

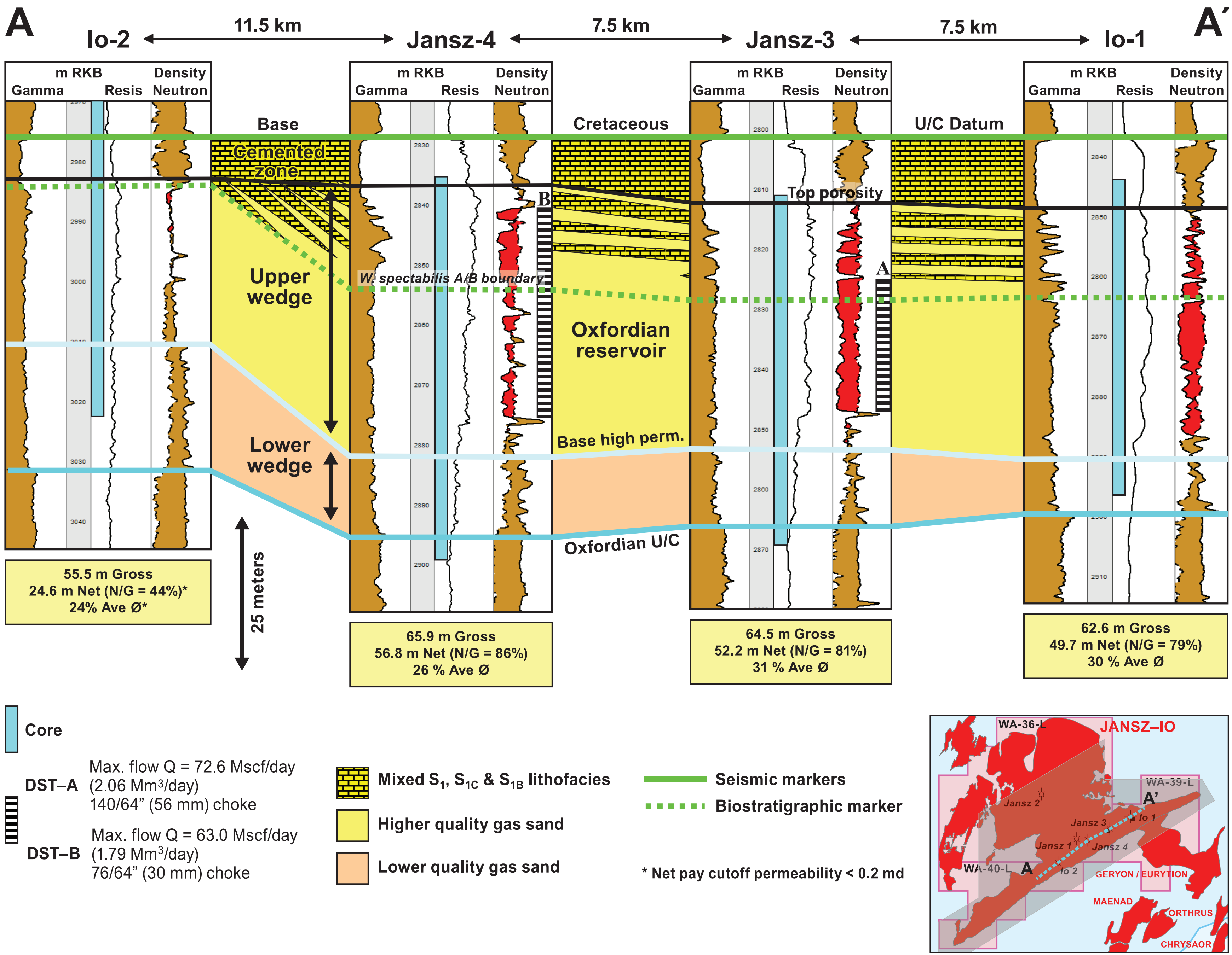

Figure 4. Stratigraphic cross section (after Jenkins et al., 2008, with permission from SPE, whose permission is required for further use). S_1 = medium grained sandstone; S_{1C} has calcite cement; and S_{1B} has berthierine clay.

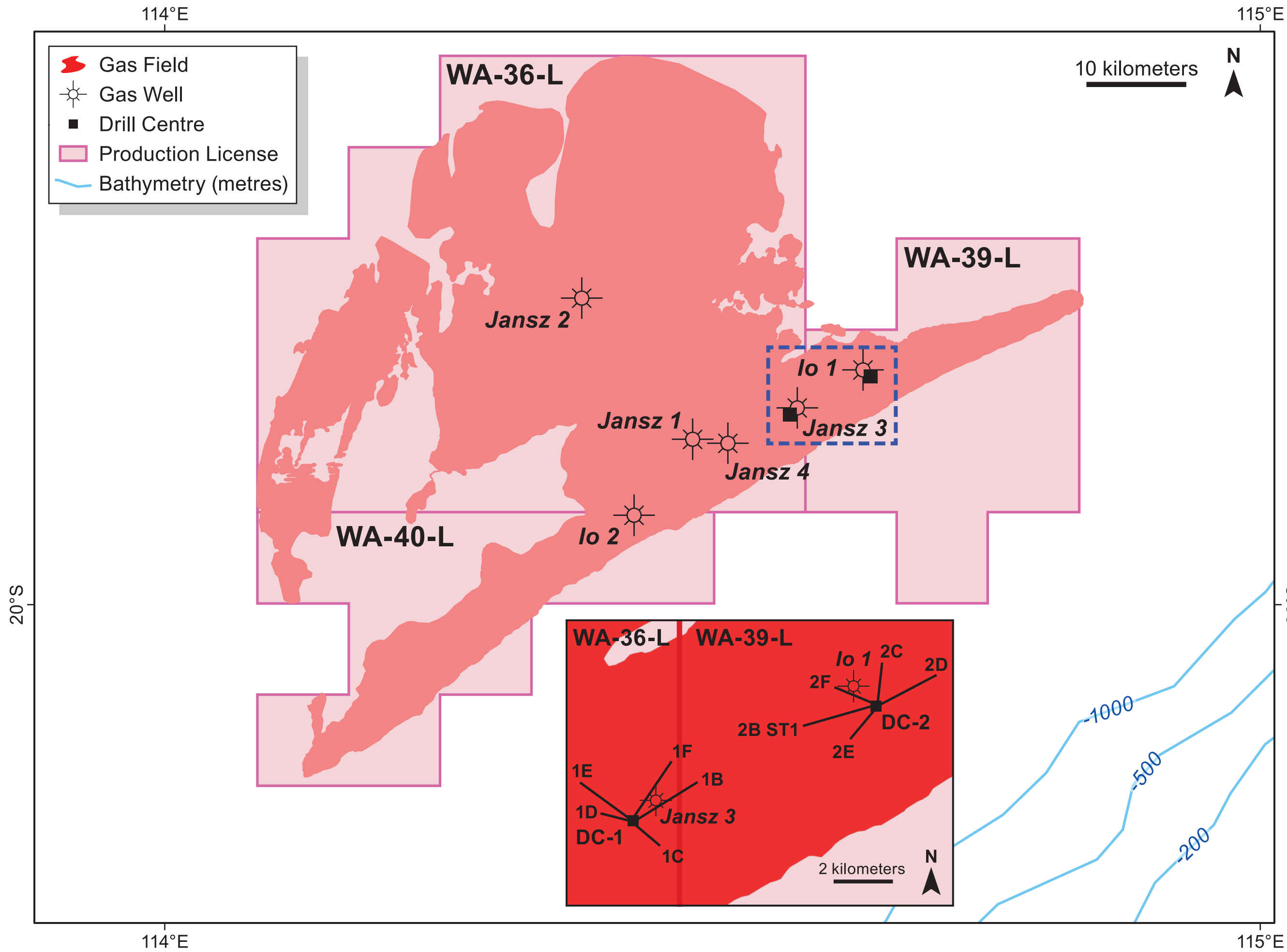

Figure 5. Exploration/delineation wells, drill centers DC-1 and DC-2 (black rectangles), and development well locations. A future drill centre (DC-3) is planned in the vicinity of the Jansz-4 well.

STRUCTURE

The depth structure map at the base-of-Cretaceous unconformity marker (Figure 4) is shown in Figure 7. The Jansz-Io structural feature is a northwest-southeast trending anticline. The Jansz-3 well is close to the structural crest of the field, and the Io-2 well is the most downdip well. The faults are extensional, were initiated by early Jurassic rifting of the Carnarvon Basin, and remained active until the early Cretaceous (Figure 3). The fault throws are up to 25 to 30 m (82 to 98 ft) at the base-of-Cretaceous unconformity marker with fault traces up to 4 km (2 mi) long.

The depth conversion issues at Jansz-Io are described in detail in Jenkins et al. (2008) and relate to the complex overburden, which consists of vertically stacked shelf-slope canyons filled with carbonates (high velocity) and lime-rich mudstones (low velocity). The composition of the sedimentary fill in the canyons varies spatially and temporally, and this causes distortion of seismic ray-paths, leading to artifacts in the seismic velocity field. The artifacts caused depth prognosis errors in the appraisal wells.

By using the depth conversion knowledge gained during the appraisal drilling program, and including an APSDM velocity field with the top of Muderong shale marker (Figure 3) as a geological constraint, a new velocity model was developed with the intent of minimizing depth conversion errors in the development wells. The velocity model proved to be robust, and the 10 development wells were drilled with minimal errors in depth prognosis and reservoir thickness prediction.

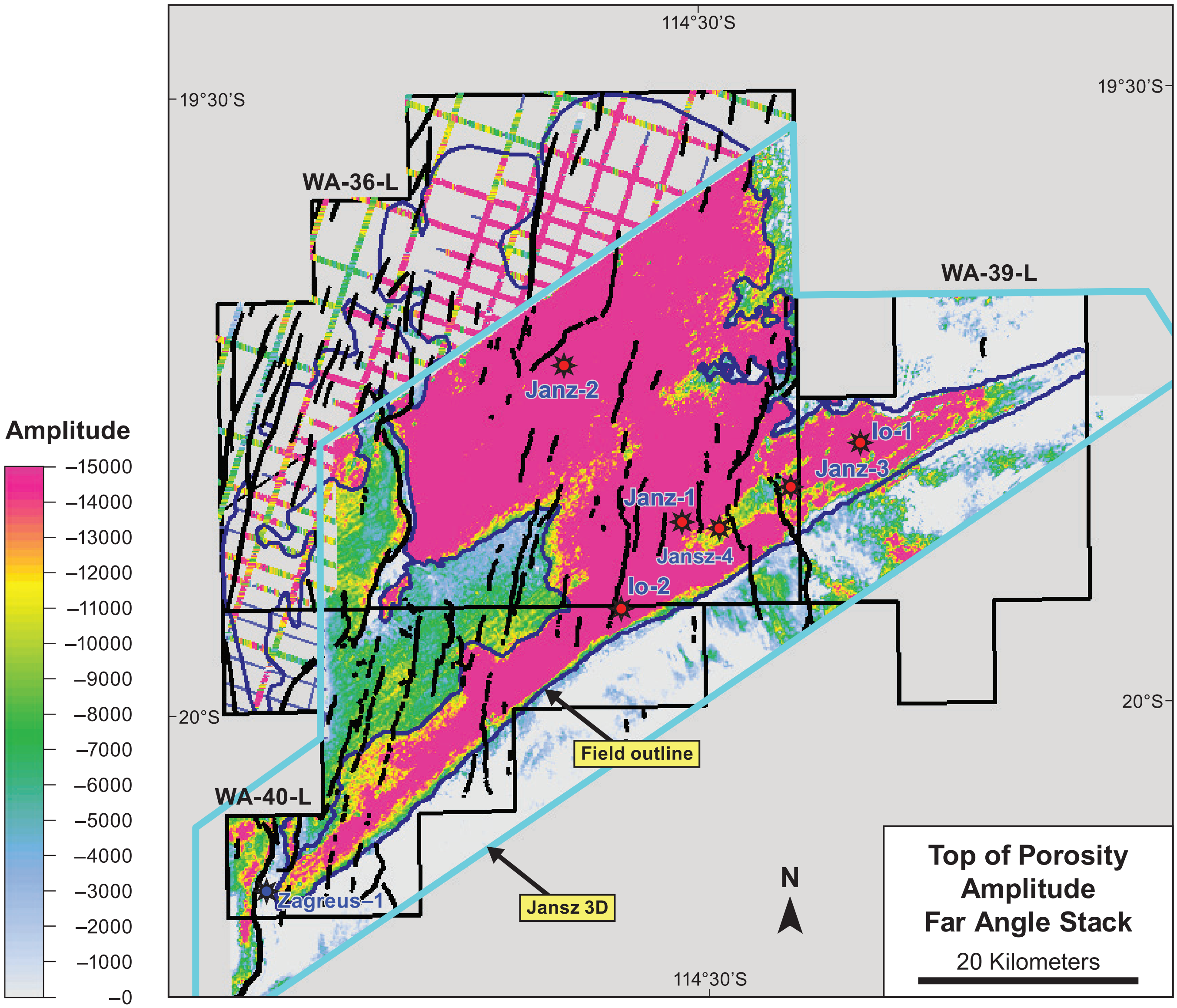

Figure 6. Seismic amplitude response at the top of porosity marker (from Jenkins et al., 2008, with permission from SPE, whose permission is required for further use).

RESERVOIR

The Upper Jurassic Jansz-Io gas-bearing sandstone can be correlated to the *W. spectabilis* dinoflagellate zone of Helby et al. (2004). The sandstone is part of the upper Dingo equivalent lithostratigraphic zone (Barber, 1988) (Figure 3). The reservoir comprises a shallow-marine sequence that prograded to the northwest during the Oxfordian. Erosion of this sequence by the Upper Jurassic and base-of-Cretaceous unconformities removed the coastal plain and most of the shoreface sections, leaving an erosional remnant of the distal lower-shoreface, offshore and open-shelf deposits. The 3-D seismic line (near-angle stack) that ties the Jansz-3 well is shown in Figure 8 with the polarity convention annotated. The base of high permeability marker is at the top of a progradational, parasequence set and dips at a low angle (less than 0.5°) to the northwest. The marker subcrops under the base-of-Cretaceous unconformity, to the southeast of the well. Mapping of the base of high permeability, top of porosity, and Oxfordian unconformity seismic markers has provided a framework for the reservoir. It has been informally subdivided into the upper wedge and lower wedge reservoir zones (Figure 4).

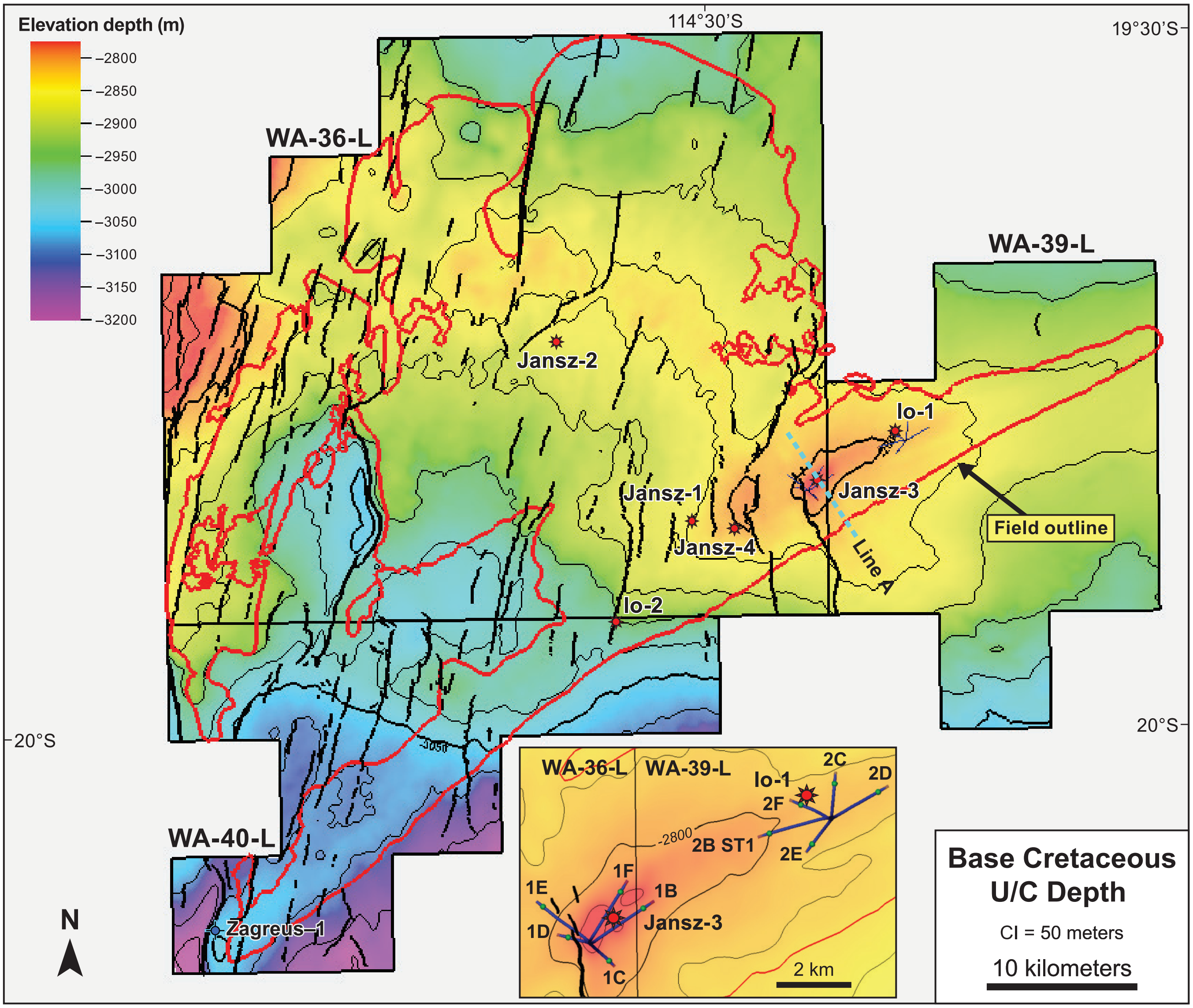

Figure 7. Depth structure map on the base-of-Cretaceous unconformity.

The upper wedge reservoir has a maximum thickness of 50 m (164 ft) and is the primary target for field development (Figure 9). The top of the upper wedge reservoir is defined by the time transgressive top of porosity marker that denotes the base of the pervasive, cemented sandstone zone (Figure 4). The lower wedge reservoir has a maximum thickness of 25 m (82 ft) and underlies the upper wedge reservoir in the core area of the field (Figure 10). A major part of the upper and lower wedge reservoirs has been removed by erosion at the Upper Jurassic and base-of-Cretaceous unconformities.

The primary development area of the field is defined by the 15 m (49 ft) isochore contour surrounding the Jansz-1, Jansz-3, Jansz-4, Io-1, and Io-2 wells. A reservoir thickness greater than 15 m (49 ft) is generally resolvable on the Jansz 3-D seismic volume, and the seismic isochron can be scaled to an isochore using interval velocities (Figure 9). Outside the primary development area, the isochore is calculated using a detuning algorithm based on the product of seismic amplitude and apparent isochron (Jenkins et al., 2008). This area includes the Jansz-2 well and most of the northwest part of the field, and it typically has a thickness less than 15 m (49 ft).

The Oxfordian shoreline had a northeast–southwest orientation, with the Jansz-3, Jansz-4, Io-1, and Io-2 wells being in a more proximal depositional

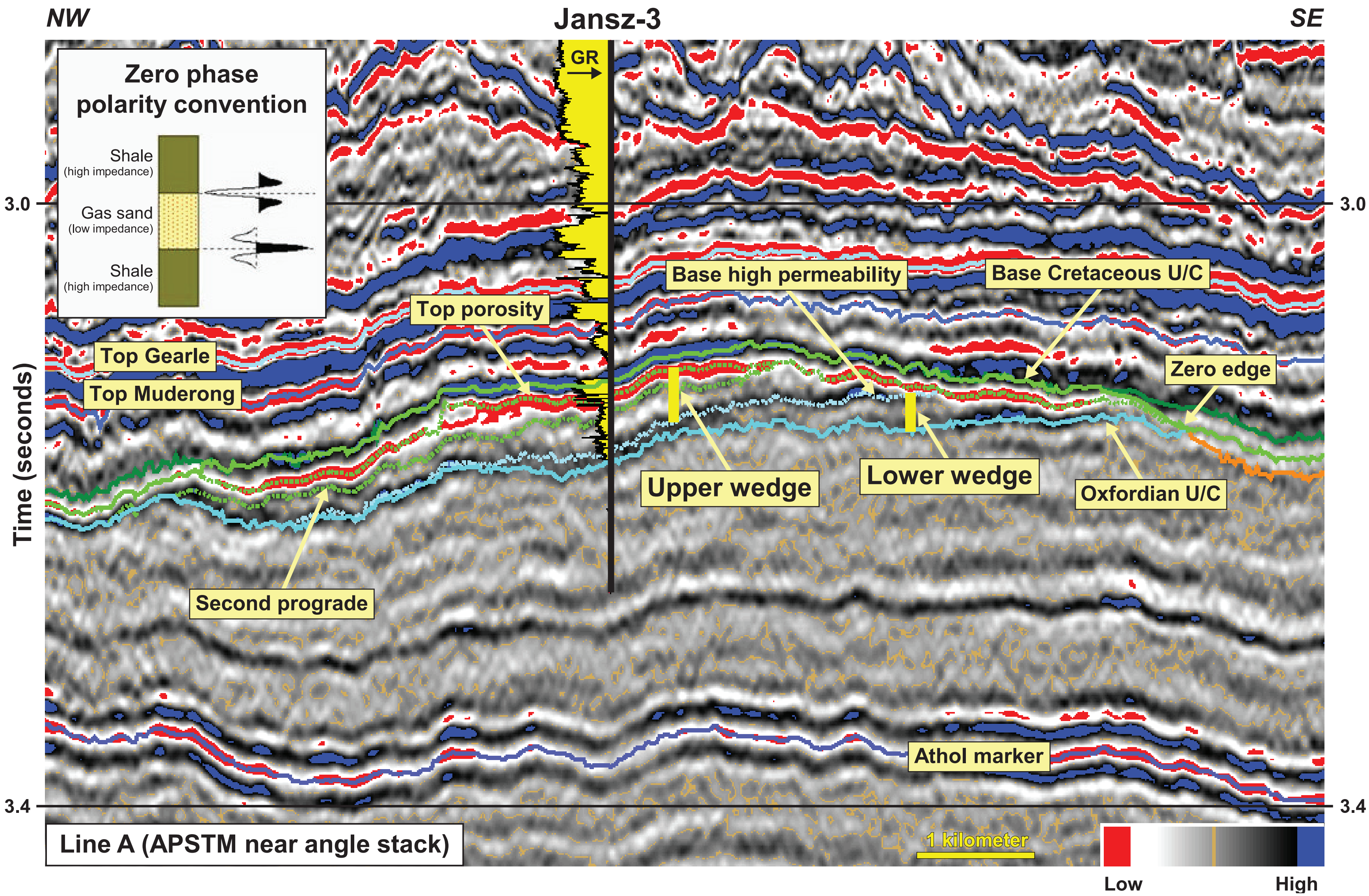

Figure 8. 3-D seismic cross line at the Jansz-3 well (from Jenkins et al., 2008, with permission from SPE, whose permission is required for further use). The line of section (Line A) is shown on the map in Figure 7.

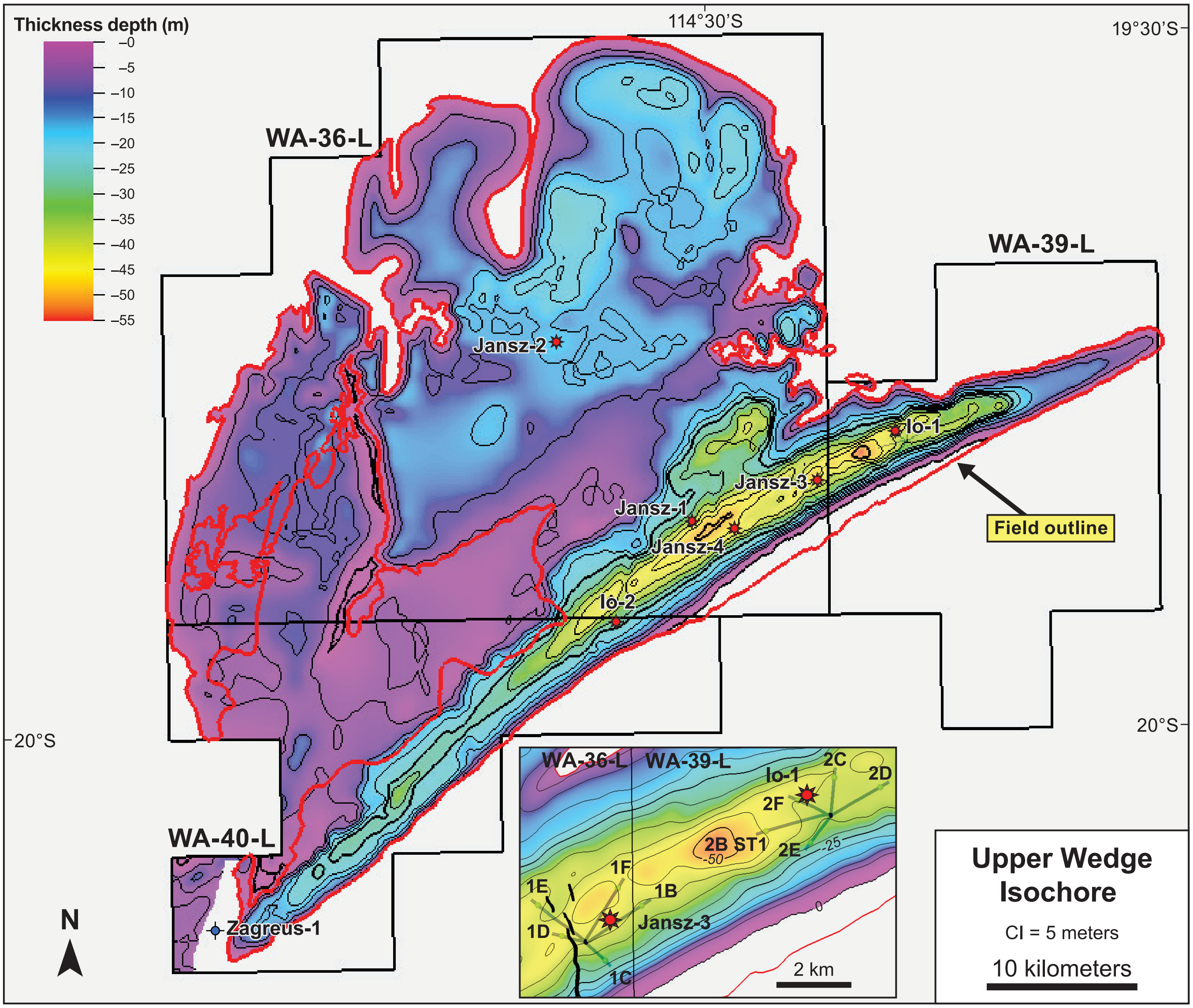

Figure 9. Upper wedge reservoir isochore.

setting than the Jansz-1 and Jansz-2 wells (Figure 11). The reservoir thins to the northwest beyond Jansz-2 and changes facies to siltstones and mudstones of the open shelf. The reservoir is composed of three primary lithofacies types as identified from core data. The highest quality reservoir and principal sands are designated lithofacies S_{42}, fine-grained sandstones with 10 to 25% clay, porosities greater than 25%, and permeabilities from 10 to 1000 md (Figure 12).

A secondary reservoir component is lithofacies S_{43}, very fine-grained sandstones with 20 to 60% clay content, porosities less than 25%, and permeabilities less than 10 md. A minor component includes poorly sorted, medium-grained sandstones of lithofacies S_1. This lithofacies is commonly cemented and stratigraphically restricted to the top of the Io-1, Io-2, Jansz-3, and Jansz-4 reservoirs (Jenkins et al., 2008).

The lithofacies model has been further validated by the results of the development drilling program. The reservoir section at Drill Center-1 and Drill Center-2 is shown on the cross-sections in Figures 13 and 14, respectively, with the nearest offset well annotated. The log data were recorded by a single LWD tool string as the high-angle wells precluded the use of conventional wireline logging techniques. The depth prognosis, thickness estimates, and reservoir quality are within the predicted predrill range for the development wells.

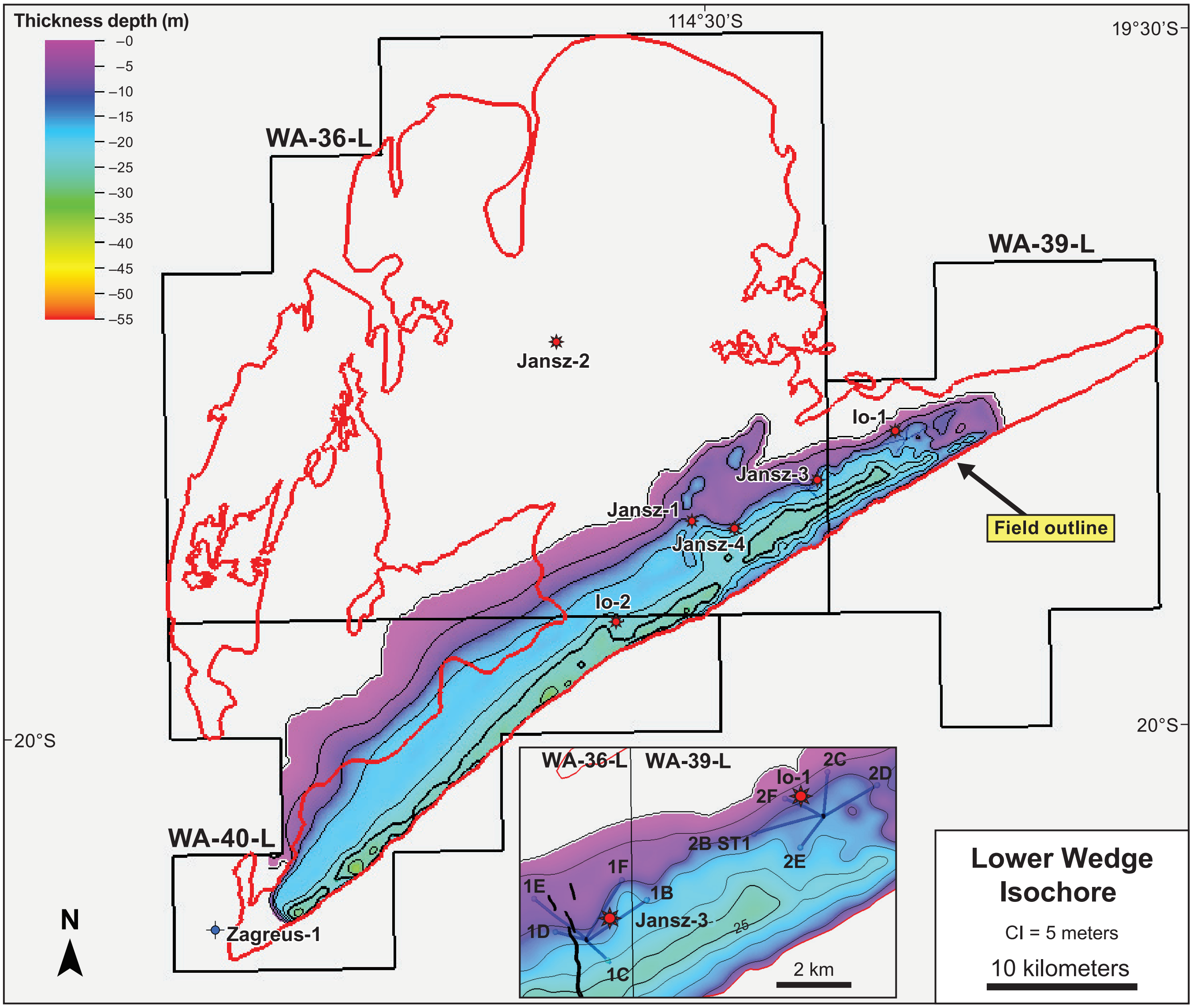

Figure 10. Lower wedge reservoir isochore.

FREE WATER LEVEL

The free water level (FWL) for Jansz-Io is interpreted from wireline MDT pressure data to be at the southwest end of the field at a depth of –3153 mSS (–10,344 ftSS), the aquifer being provided by the normally pressured fluvial-deltaic sandstones of the Mungaroo Formation (Figure 15). The Mungaroo Formation aquifer is juxtaposed with the Oxfordian reservoir across a major tectonic fault. The FWL for the field is more than 20 km (12 mi) from the development area, and water production in the development wells is considered unlikely. The LKG for the field is at –2970 mSS (–9744 ftSS) at the Io-2 well.

DEVELOPMENT OVERVIEW

The field development program includes subsea completions from three drill centers placed on the seafloor in the core development area of the field (Figure 5). A subsea production pipeline, hydrate inhibitor pipeline, and control umbilical connect the field to the LNG processing plant located on Barrow Island, some 140 km (87 mi) to the southeast of Jansz-Io.

Two drilling campaigns are planned. Ten wells were drilled in the first campaign (between 2012 and 2014), to be followed by five wells in the second campaign, the timing being dependent on field performance.

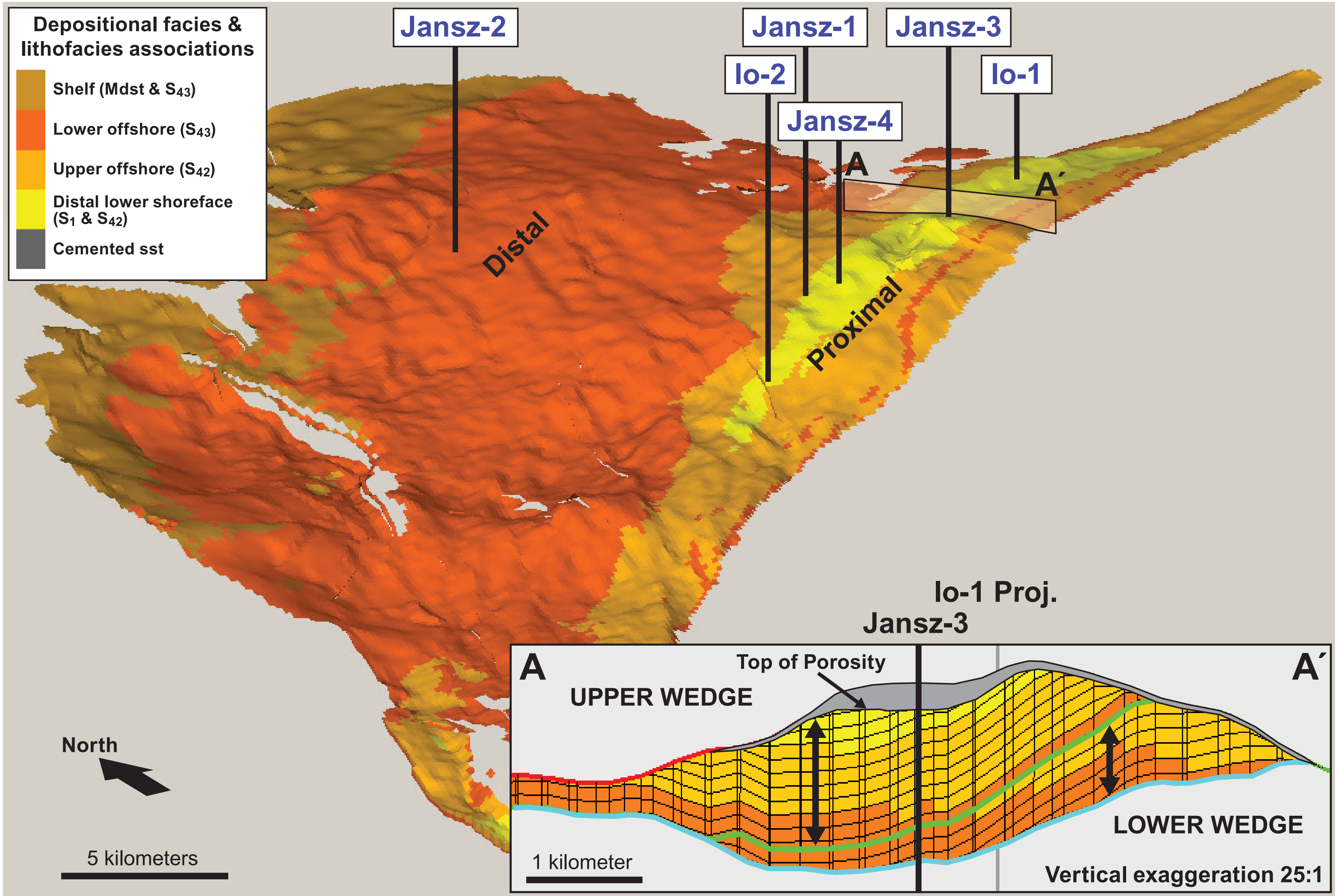

Figure 11. Depositional facies. The map is at the top of porosity and excludes the cemented sandstone (from Jenkins et al., 2008, with permission from SPE, whose permission is required for further use).

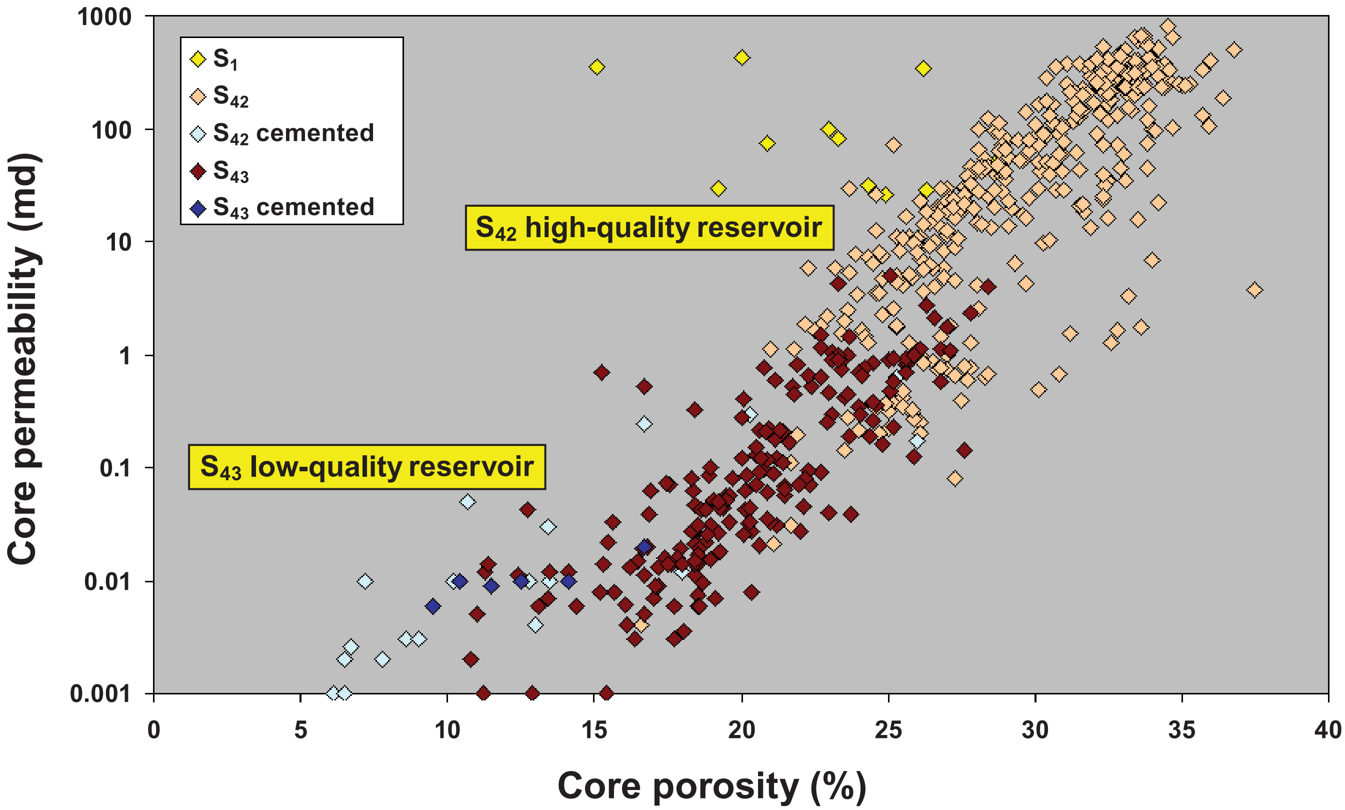

Figure 12. Lithofacies types and reservoir quality measured from core plugs analyzed at overburden conditions (from Jenkins et al., 2008, with permission from SPE, whose permission is required for further use).

The 15 big-bore wells are planned to be high angle (80°) to enhance reservoir productivity, and open-hole gravel pack completions are required for sand control in the Oxfordian reservoir.

Depletion drive is expected to be the primary mechanism for gas production due to limited connectivity with the Mungaroo Formation aquifer, and compression will be required to maximize the production plateau and extend field life up to 50 years.

RESOURCE SIZE

The results of a model-based uncertainty analysis (Jenkins et al., 2008) describe OGIP range, expressed as an exceedance probability plot, in Figure 16. The OGIP for the Jansz-Io Oxfordian reservoir has a probabilistic range from 320 to 946 Gm^3 (11 to 33 tcf), with a p50 value of 632 Gm^3 (22 tcf).

The ultimate recovered gas for the field will depend on both the development plan and reservoir performance. For the current 15-well development plan, the resource estimates range from 201 to 442 Gm^3 (7 to 16 tcf).

CONCLUSIONS

The Jansz-Io gas field is a large gas accumulation in a structural/stratigraphic trap that was discovered in the Carnarvon Basin in 2000, the basin being at a mature stage for large conventional structural hydrocarbon plays. The stratigraphic component of the Jansz-Io trap relates to a combination of erosion of the reservoir by regional unconformities associated with Upper Jurassic rifting and proximal-to-distal facies changes from sandstone to mudstone. The reservoir has been delineated using 2-D and 3-D seismic surveys to map the bounding surfaces with the edges of the field defined by a prominent seismic amplitude anomaly on far offset stacks.

The reservoir was deposited in a shallow-marine environment, but the upper-shoreface and most of the lower-shoreface section have been removed due to uplift and erosion during the Upper Jurassic, leaving the muddy sandstones of the distal lower-shoreface and offshore zones. Although these are lower quality facies, the shallow burial depth of the reservoir has preserved primary porosity and permeability in the muddy sandstones.

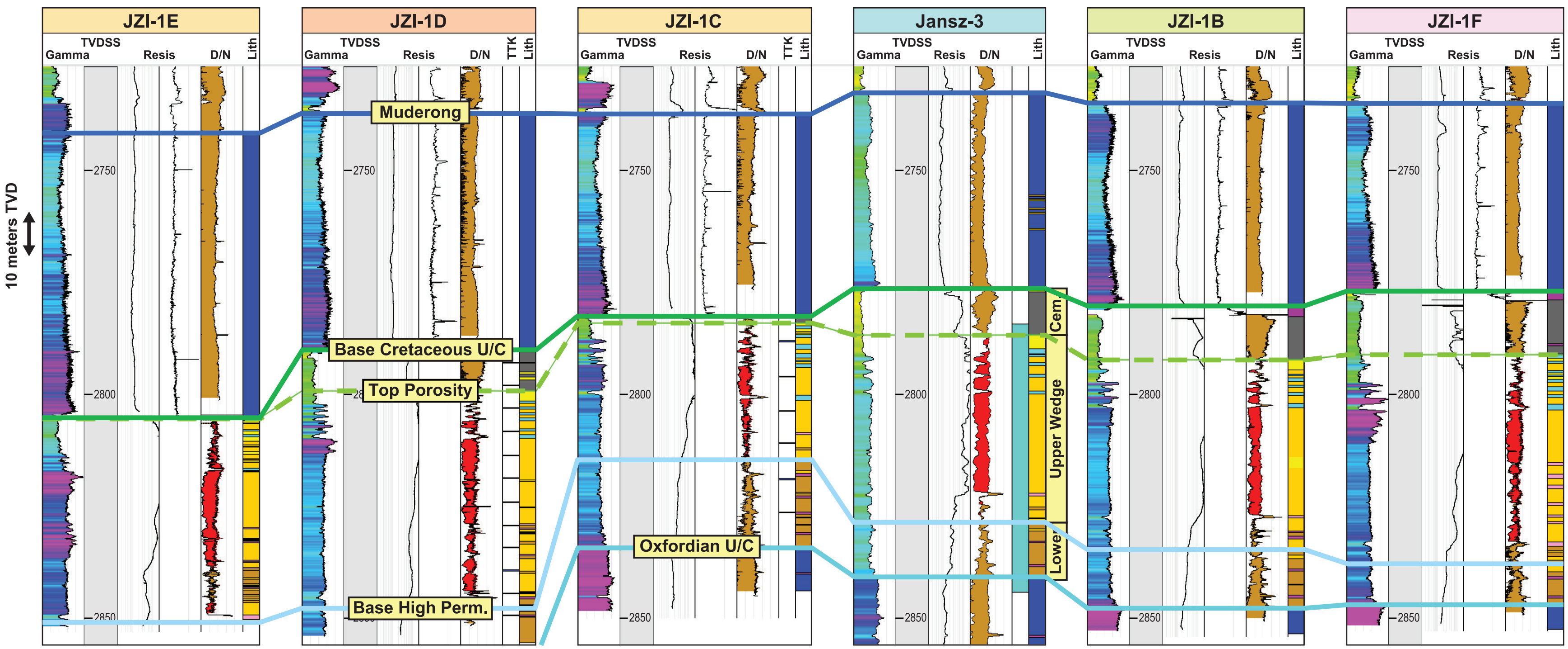

Figure 13. Structural cross section at DC-1. Well and drill center locations are shown in Figure 5. Log tracks from left to right: Gamma = gamma ray; TVDSS = true vertical depth from mean sea level datum; Resistivity, D/N = density/neutron; TTK = formation pressure; Cyan bar = core interval; Lith = lithology.

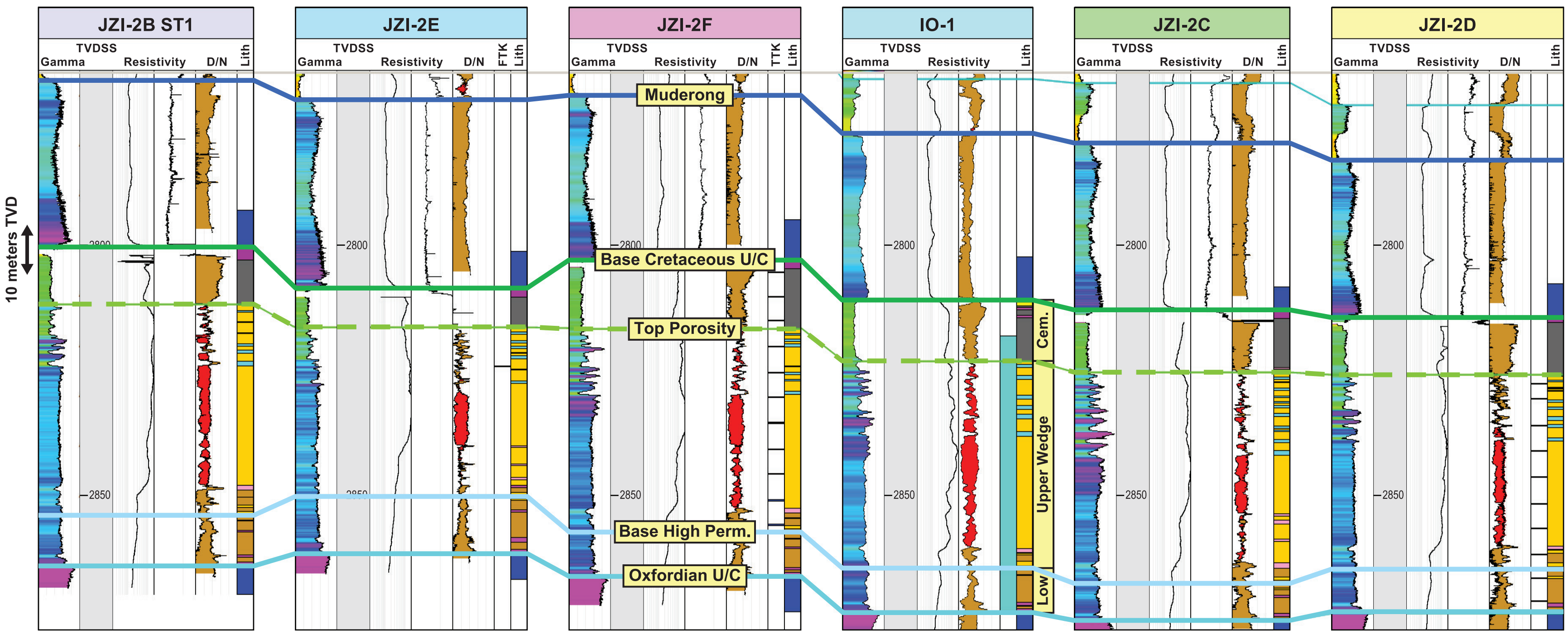

Figure 14. Structural cross section at DC-2. Well and drill center locations are shown in Figure 5. Log tracks from left to right: Gamma = gamma ray; TVDSS = true vertical depth from mean sea level datum; Resistivity, D/N = density/neutron; FTK = gas sample and formation pressure; TTK = formation pressure; Cyan bar = core interval; Lith = lithology.

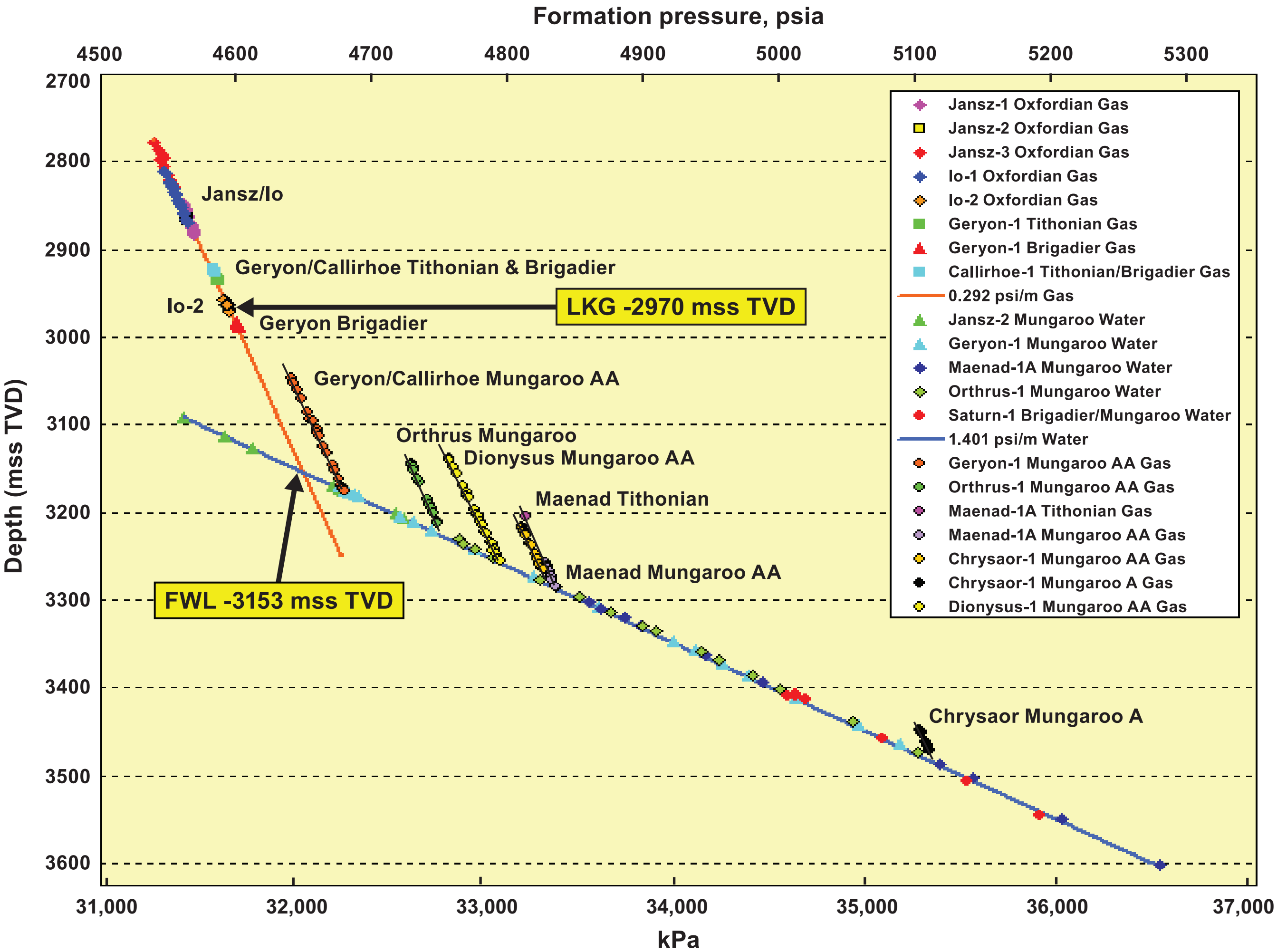

Figure 15. Jansz-Io fluid contacts. Depth is true vertical measured from mean sea level datum (from Jenkins et al., 2008, with permission from SPE, whose permission is required for further use).

The resource description and uncertainty analyses indicate the Jansz-Io gas field is a giant gas accumulation that will provide feedstock to produce LNG for the greater Gorgon LNG development. The first phase of the field development has been executed with 10 development wells successfully drilled at 75 to 80° through the reservoir. The wells have been completed with open-hole gravel packs and connected to the subsea in-field facilities and flowline.

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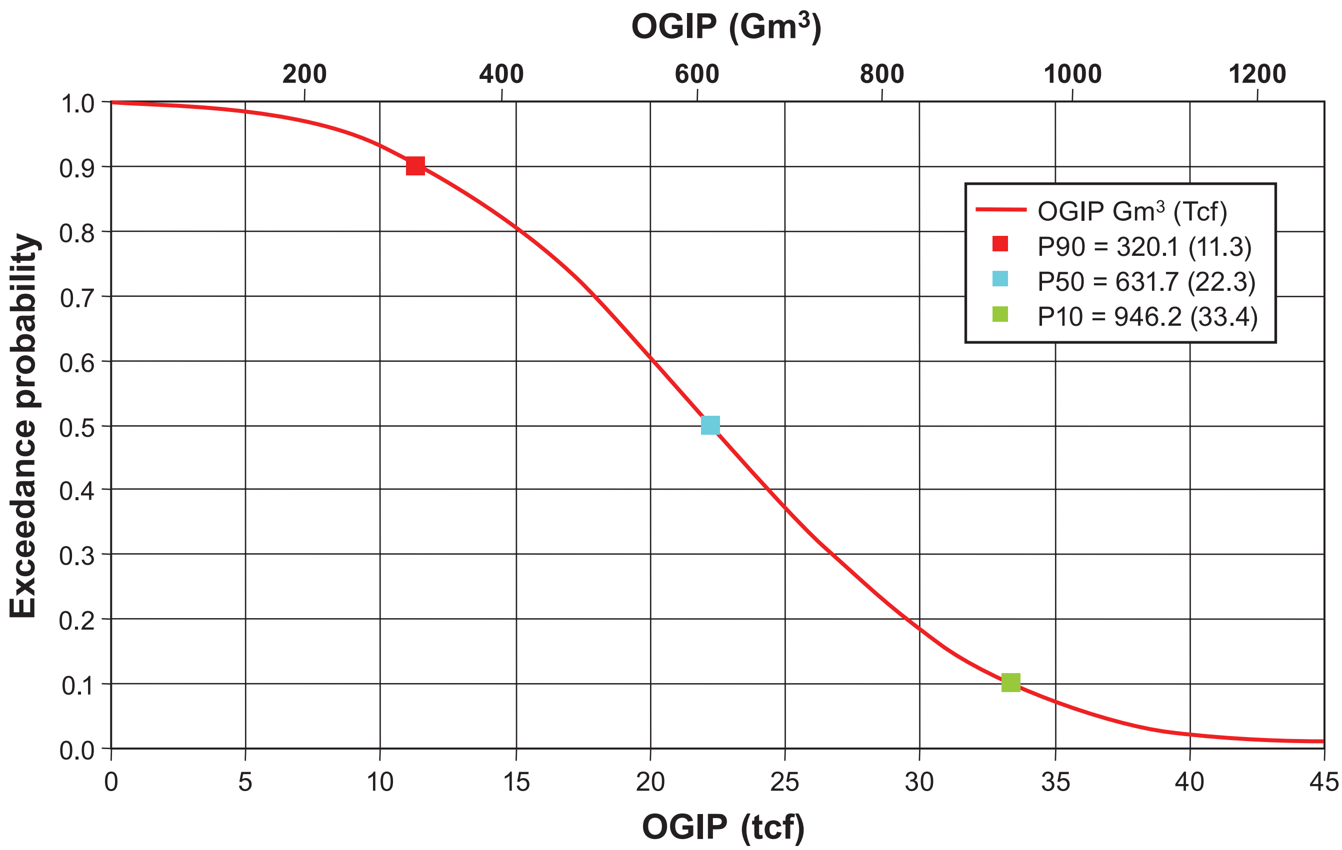

Figure 16. Resource size original gas in place (OGIP) (after Jenkins et al., 2008, with permission from SPE, whose permission is required for further use).

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