

# CNR International

## RELINQUISHMENT REPORT

### Relinquishment Report for P329 Licence

NUMBER: BFD-CNR-GG-REL-00002

ORIGINATOR: Adam Styles

DATE: 13/12/2023

Date	Issue Description	Revision	By	Check	Approver
13/12/2023	Issued for submission	A1	AS	TJ	CT

Approval	Date	Signature
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### 1. LICENCE INFORMATION

P329 is in the East Shetland Basin due east of the Ninian Field. It initially contained the Staffa Field (now named Mansell) as shown in Figure 1.

Table 1 - P329 Licence Information.

Licence Number	P329
Licence Round	7
Date	16 December 1980
Licence Type	Traditional
Block Numbers	3/8b

Retained acreage at the time of relinquishment is a P-shaped region in the northwest of the initial licence area adjacent to the Ninian Field (Figure 1). This was within the PRT determination of the Ninian Field and classified as a producing area in a 2016 Deed of Amendment. Redetermination of the Ninian PRT boundary was agreed in 2023, exclude 3/8b from the Ninian Field and allowing full relinquishment of the licence. Justification for this change is presented in Section 5.

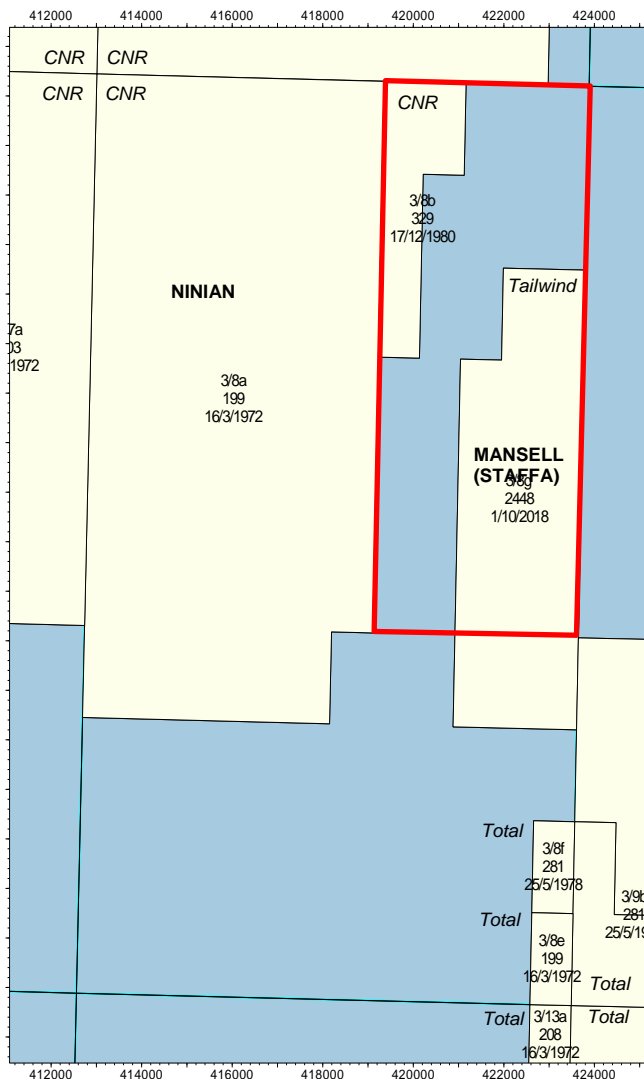


Figure 1 - Licenced area (yellow), unlicensed area (blue) and fields (orange), October 2023. Labels are centred on the licenced areas and display block, licence number and licence start date.

The initial P329 licence area is outlined in red and contained the Staffa Field, whose field area was relinquished soon after Staffa was decommissioned. It is now licensed under P2448 Block 3/8g and has not been redeveloped at the time of this report.

The extant licence area at time of relinquishment was the P-shaped area immediately adjacent to P199 Block 3/8a and the Ninian Field.

## 2. LICENCE SYNOPSIS

P329 is a single-block licence that was awarded to BP, in the 7th Round at a time of exploration and appraisal of satellite prospects adjacent to the producing platforms throughout the East Shetland Basin. The block lies southeast of the Ninian South Platform which came on production in January 1979, two years prior to the licence grant.


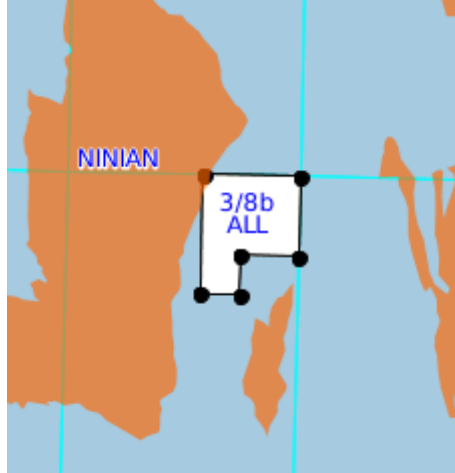

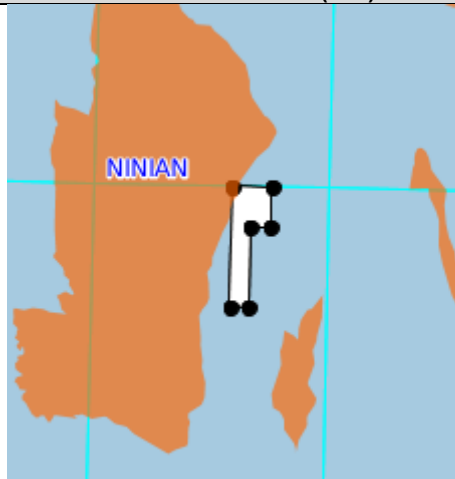
### 2.1 Licence Events

The history of P329 is detailed in Tables 2 and 3.

Table 2 – P329 Licence Events.

Date	Beneficial Interests [ <sup>†</sup> Administrator, <sup>††</sup> Operator]	Description
16/12/1980	<b>Block 3/8b:</b> BP Petroleum Development Limited <sup>††</sup> 50% Ranger Oil (U.K.) Limited 20% Scottish Canadian Oil & Trans Co Limited 30%	<b>Grant of P329 licence to: 'search and bore and get petroleum in Block 3/8b'.</b> Total area: 50.6 km <sup>2</sup>
30/08/1988	<b>Block 3/8b:</b> LASMO North Sea PLC <sup>††</sup> 60% Ranger Oil (U.K.) Limited 40%	Scottish Canadian Oil & Trans Co Ltd renamed LASMO North Sea PLC. <b>Equity transfer</b> from BP Petroleum Development Ltd to LASMO North Sea PLC and Ranger Oil (U.K.) Ltd. <b>Change of administrator and operator</b>
27/11/1998	<b>Block 3/8b:</b> Ranger Oil (U.K.) Limited <sup>††</sup> 100%	<b>Equity transfer</b> from LASMO North Sea PLC to Ranger Oil (U.K.) Limited. <b>Change of administrator and operator</b>
17/12/1998	<b>Block 3/8b:</b> Ranger Oil (U.K.) Limited <sup>††</sup> 100%	<b>Part relinquishment</b> of 3/8b including Staffa Field area. Retained area: 20.2 km <sup>2</sup>
10/06/2003	<b>Block 3/8b:</b> CNR International (U.K.) Limited <sup>††</sup> 100% Block 3/8b Fields: Ninian <b>Field: Ninian, Block 3/8b (ALL):</b> CNR International (U.K.) Limited <sup>†</sup> 87.06% ENI UK Limited 12.94%	<b>Equity transfer</b> from Ranger Oil (U.K.) Ltd to CNR International (U.K.) Ltd upon company acquisition. <b>Change of administrator and operator.</b> <b>Subarea change</b> to All (ALL) Fields: Ninian. <b>Part-transfer of beneficial interest in Ninian Field</b> from CNR International (U.K.) Ltd to ENI UK Ltd
31/12/2007	<b>Block 3/8b:</b> CNR International (U.K.) Limited <sup>††</sup> 100% Block 3/8b Fields: Ninian <b>Field: Ninian, Block 3/8b (ALL):</b> CNR International (U.K.) Limited <sup>†</sup> 87.06% ENI UK Limited 12.94%	<b>Part relinquishment</b> of 3/8b. Retained area: 13.5km <sup>2</sup>
28/09/2009	<b>Block 3/8b:</b> CNR International (U.K.) Limited <sup>††</sup> 100% Block 3/8b Fields: Ninian <b>Field: Ninian, Block 3/8b (ALL):</b> CNR International (U.K.) Limited <sup>†</sup> 87.06088% ENI UK Limited 12.93912%	Minor equity adjustment
29/09/2009	<b>Block 3/8b:</b> CNR International (U.K.) Limited <sup>††</sup> 100% Block 3/8b Fields: Ninian <b>Field: Ninian, Block 3/8b (ALL):</b> CNR International (U.K.) Limited <sup>†</sup> 87.06088% JX Nippon Exploration and Production (U.K.) Limited 12.93912%	Transfer of field beneficial interest from ENI UK Ltd to JX Nippon Exploration and Production (U.K.) Ltd
16/12/2016	<b>Block 3/8b:</b> CNR International (U.K.) Limited <sup>††</sup> 100% <b>Field: Ninian, Block 3/8b (ALL):</b> CNR International (U.K.) Limited <sup>†</sup> 87.06088% JX Nippon Exploration and Production (U.K.) Limited 12.93912%	<b>Part relinquishment</b> of 3/8b. Retained area: 6.739km <sup>2</sup>
26/06/2018	<b>Block 3/8b:</b> CNR International (U.K.) Limited <sup>††</sup> 100% <b>Field: Ninian, Block 3/8b (ALL):</b> CNR International (U.K.) Limited <sup>†</sup> 100%	Transfer of beneficial interest from JX Nippon Exploration and Production (U.K.) Ltd to CNR International (U.K.) Ltd.
15/12/2023	<b>Block 3/8b:</b> CNR International (U.K.) Limited <sup>†</sup> 0%	<b>Subarea change</b> , 3/8b removed from the Ninian Field. Licence end.

Table 3 – P329 licence area changes, Data and maps collated from UK Energy Portal.

16 December 1980: Block 3/8b (ALL)		17 December 1998: Block 3/8b (ALL)	
	<p>Block 3/8b, defined on 16th December 1980, is the region bounded by the following coordinates:</p> <ol style="list-style-type: none"> <li>(1) 60°50'00.000"N 1°31'00.000"E</li> <li>(2) 60°44'00.000"N 1°31'00.000"E</li> <li>(3) 60°44'00.000"N 1°36'00.000"E</li> <li>(4) 60°50'00.000"N 1°36'00.000"E</li> <li>(5) 60°50'00.000"N 1°31'00.000"E</li> </ol> <p>Subareas: ALL (ALL) as above</p> <p>All exploration, appraisal and development activity took place prior to any changes in licence extent</p>		<p>Block 3/8b, defined on 17th December 1998, is the region bounded by the following coordinates:</p> <ol style="list-style-type: none"> <li>(1) 60°50'00.000"N 1°31'00.000"E</li> <li>(2) 60°50'00.000"N 1°36'00.000"E</li> <li>(3) 60°48'00.000"N 1°36'00.000"E</li> <li>(4) 60°48'00.000"N 1°33'00.000"E</li> <li>(5) 60°47'00.000"N 1°33'00.000"E</li> <li>(6) 60°47'00.000"N 1°31'00.000"E</li> <li>(7) 60°50'00.000"N 1°31'00.000"E</li> </ol> <p>Subareas: ALL (ALL) as above.</p> <p>Relinquished southern portion included the Staffa field area</p>
	<p>Block 3/8b, defined on 31st December 2007, is the region bounded by the following coordinates:</p> <ol style="list-style-type: none"> <li>(1) 60°50'00.000"N 1°31'00.000"E</li> <li>(2) 60°50'00.000"N 1°34'00.000"E</li> <li>(3) 60°48'00.000"N 1°34'00.000"E</li> <li>(4) 60°48'00.000"N 1°33'00.000"E</li> <li>(5) 60°47'00.000"N 1°33'00.000"E</li> <li>(6) 60°47'00.000"N 1°31'00.000"E</li> <li>(7) 60°50'00.000"N 1°31'00.000"E</li> </ol> <p>Subareas: ALL (ALL) as above</p> <p>Relinquishment to only retain the area over the Ronan prospect, drillable from Ninian</p>		<p>Block 3/8b, defined on 16th December 2016, is the region bounded by the following coordinates:</p> <ol style="list-style-type: none"> <li>(1) 60°50'00.000"N 1°31'00.000"E</li> <li>(2) 60°50'00.000"N 1°33'00.000"E</li> <li>(3) 60°49'00.000"N 1°33'00.000"E</li> <li>(4) 60°49'00.000"N 1°32'00.000"E</li> <li>(5) 60°47'00.000"N 1°32'00.000"E</li> <li>(6) 60°47'00.000"N 1°31'00.000"E</li> <li>(7) 60°50'00.000"N 1°31'00.000"E</li> </ol> <p>Subareas: ALL (ALL) as above.</p> <p>Reduction in area to Ninian PRT boundary</p>

### 3. WORK PROGRAMME SUMMARY

There were no wells within the extant licence area at the time of relinquishment and no remaining work obligations. The information below details full licence history for completeness.

#### 3.1 Initial term (1980-1986)

P329 Schedule 4 required two exploration wells to be drilled within 5 years.

Twenty-one 2D seismic lines were shot to allow evaluation of prospective Brent Group targets. Proprietary 3D seismic data acquired over the Columba terraces in blocks 3/7 and 3/8a in 1985 partially covers the south of 3/8b. Seismic evaluation confirmed the presence of a tilted fault block in the structural low between the Ninian and Alwyn Fields.

Staffa was discovered by 3/08b- 10 in early 1986 and further appraised by 3/08b- 11 later that year (Table 4).

Table 4 – P329 wells.

Well	Spud Date	Description	Well Status
Phase 1			
3/08b- 10	06/03/85	<b>Staffa discovery</b> wildcat targeted an interpreted Jurassic fault block southeast of Ninian. It discovered a 105m oil column in Ness and Tarbert Formation and tested 2500-4100bopd of light, sour oil. P50 STOIP was estimated at 59MMbbls, sufficient for a tieback development to Alwyn or Ninian and the accumulation was named Staffa. It was suspended and recompleted in 1992 as a Staffa producer.	AB3
3/08b- 11	28/01/86	<b>Staffa appraisal</b> drilled 3km north of 3/08b- 10 and found low permeability Brent sandstones. It failed to flow on test and was not in communication with the discovery well.	AB3
Phase 2			
3/08b- 13	12/11/87	<b>Staffa appraisal</b> drilled 1km NW of 3/08b- 10 and found low permeability Brent. It failed to flow and injectivity tests suggested <0.1mD permeability. STOIP was revised down to 52MMbbls. BP exited the licence in 1988.	AB3
3/08b- 14	05/06/89	<b>Staffa appraisal</b> testing the southern limit of the field, down-dip reservoir quality and fluid contacts. Oil-charged Tarbert and Ness core was cut but was found to be low permeability. The Broom Formation was cut out by a normal fault. Three DSTs taken - two did not flow and the third achieved 600-1050bopd with higher GOR and Bo than expected, suggesting compartmentalisation	AB3
3/08b- 14Z	12/09/89	<b>Staffa appraisal</b> up dip from 3/08b- 10. It tested 6056bopd in the Ness and 8200bopd in the Tarbert and was suspended. The well was recompleted in 1992 as a Staffa producer.	AB3

#### 3.2 Second Term (1986-1990)

Appraisal of the Staffa prospect comprised 3 further wells (Table 4) which demonstrated an economic oil accumulation in the Tarbert and Ness Formations of the Brent Group within a tilted fault-block.

#### 3.3 Staffa Field Development (1990-1998)

Annex B was approved in 1990, with 3/08b- 10 and 3/08b-14Z to be recompleted as producers tied back to the Ninian South Platform (NSP) to produce under natural depletion. STOIP was estimated at 23-31MMstb with uncertainty in oil-water contact, fault compartmentalisation and base seal. Reserves were estimated at 5.5MMstb.

A Ninian Annex B followed in 1991 detailing facilities modifications to handle satellite field tiebacks (Lyell, Staffa and Strathspey). Staffa production was via an 8-inch subsea production flowline, exporting fluids to the Ninian Southern Platform () for processing and direct export to the Sullom Voe Terminal via the Ninian Pipeline. Peak

production of 15,000bopd and 20MMscfd gas was predicted with water handling facilities for 40,000bwpd. Construction proceeded in 1991-2.

Staffa produced 3.9MMbbl between March 1992 and November 1994. Initial production was promising before the export line waxed and ceased flowing after 15 months. After an unsuccessful solvent treatment, a partial line replacement allowed production to resume in late 1993. GOR increased and rate fell as the pool depleted below bubble point. The export line again waxed up in early 1994 with field recovery at 13% and 0% watercut (Gluyas and Hitchens 2003). Further extraction was not economic at that time and LASMO obtained DTI approval for cessation of production in March 1995.

All wells were permanently abandoned in 1995-6 using the CSO Seawell DSV. Remaining facilities and pipelines were removed in 1997, and the field area was relinquished in December 1998.

Despite challenges experienced during Staffa's short life, close proximity to Ninian South and Central Platforms made them a target for further development. CNR International (U.K.) Ltd relicensed the area as P1075 Block 3/8d in 2003 under a drill-or-drop 3 year term. Despite operating adjacent platforms, an economic development could not be found and the licence was relinquished in 2006. The area was licensed again by Decipher Energy Ltd as P2448 Block 3/8g in 2018, remains extant and is operated by Tailwind Energy Chinook Ltd (Serica Energy) at the time of this report.

#### **4. DATABASE**

The wells used in evaluation of licence prospectivity are listed in Table 5. Available seismic data for P329 is listed in

Table and shown on

Figure a and b.

Table 5 – Wells used in prospectivity evaluation of licence P329. P329 wells are from the Staffa Field and P202 wells from the Ninian Field

Well	Spud Date	Completion Date	Wellhead Longitude	Wellhead Latitude	Total Depth /ft	TD Formation	Licence
3/08b- 10	06/03/1985	19/06/1985	1.579903	60.747286	14884.82	Statfjord Formation	P329
3/08b- 11	28/01/1986	15/05/1986	1.591139	60.771972	15445.80	Statfjord Formation	P329
3/08b- 13	12/11/1987	07/12/1995	1.580000	60.752389	15386.80	Dunlin Group	P329
3/08b- 14	06/06/1989	12/09/1989	1.579914	60.747238	15541.01	Dunlin Group	P329
3/08b- 14Z	12/09/1989	04/12/1991	1.579914	60.747238	14776.41	Dunlin Group	P329
3/03- 8	21/02/1980	15/06/1980	1.542889	60.877361	13802	Keuper Marl Formaiton	P202
3/03- 12	09/09/2003	07/01/2004	1.558828	60.847888	13709	Broom Formation	P202
3/03-C90Y	09/09/2007	03/01/2008	1.510144	60.828652	20045	Ness Formation (Slump)	P202

Table 6 – Seismic surveys over P329

Survey	Licence	Owner	Original Owner	Acquisition Contractor	Acquisition Year	Survey Code	Maps	Survey
<i>Covering extant area as at November 2023</i>								
CV833F0001	P199/329	CNR	Chevron	Geco-Prakla	1983	CV__1983seis0002	No	PROPRIETARY 3D
<i>Surveys that cross area</i>								
BP812D2020	P329	CNR	BP	Geco	1985	BP__1981seis0023	Yes	PROPRIETARY 2D
BP862D1022	P329	ENI	BP	Digital Exploration	1986	BP__1986seis0011	Yes	PROPRIETARY 2D
LH892D1003	P199	CNR	LASMO	Seismograph Service	1989	LH__1989seis0005	Yes	PROPRIETARY 2D
BU742D1001	TBC	CNR	Premier Oil Exploration	Digicon	1974	BU__1974seis0001	No	PROPRIETARY 2D
BP853F0001	P199	CNR	BP	Geco-Prakla	1985	BP__1985seis0014	No	PROPRIETARY 3D

Figure 2a – Seismic lines over P329

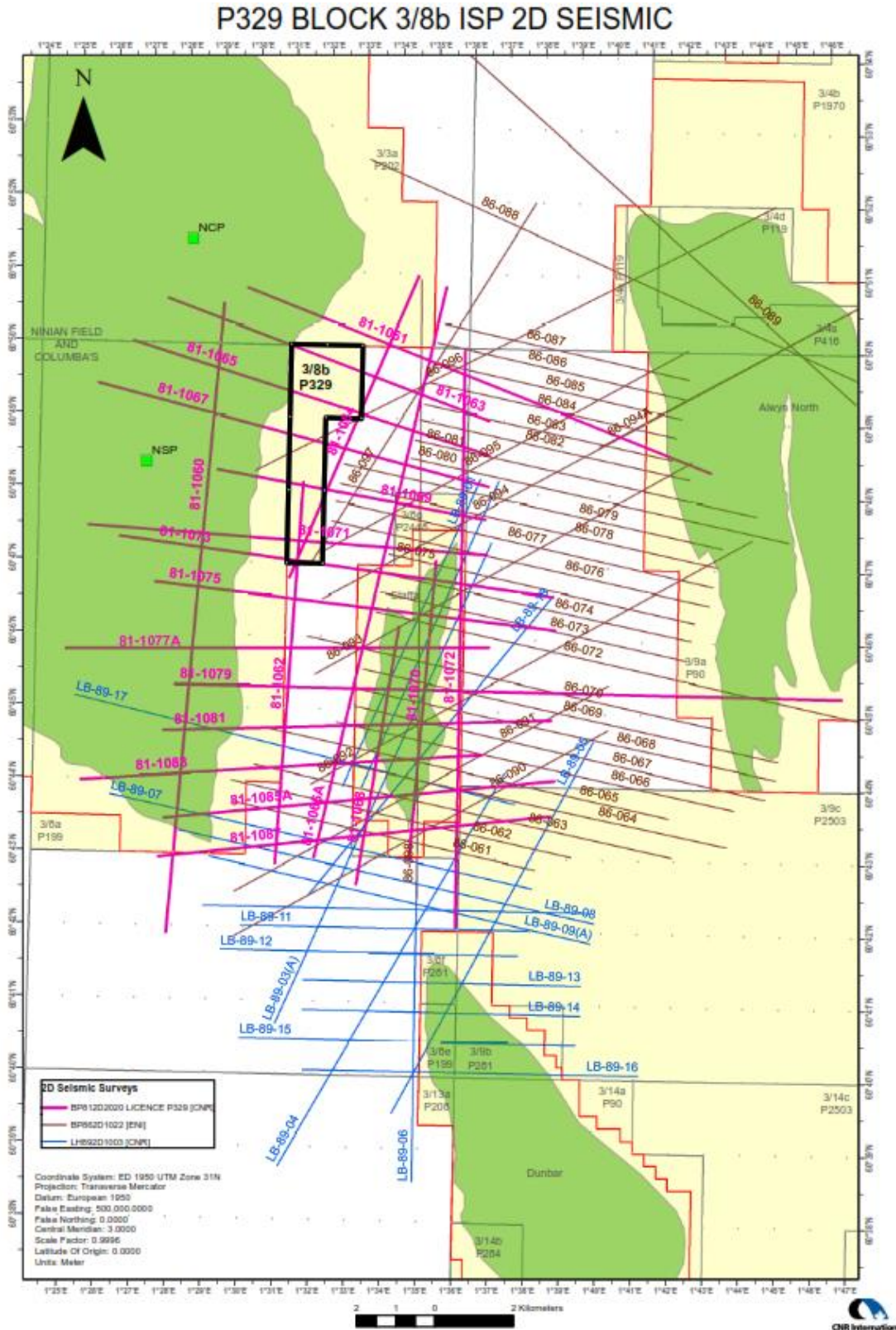
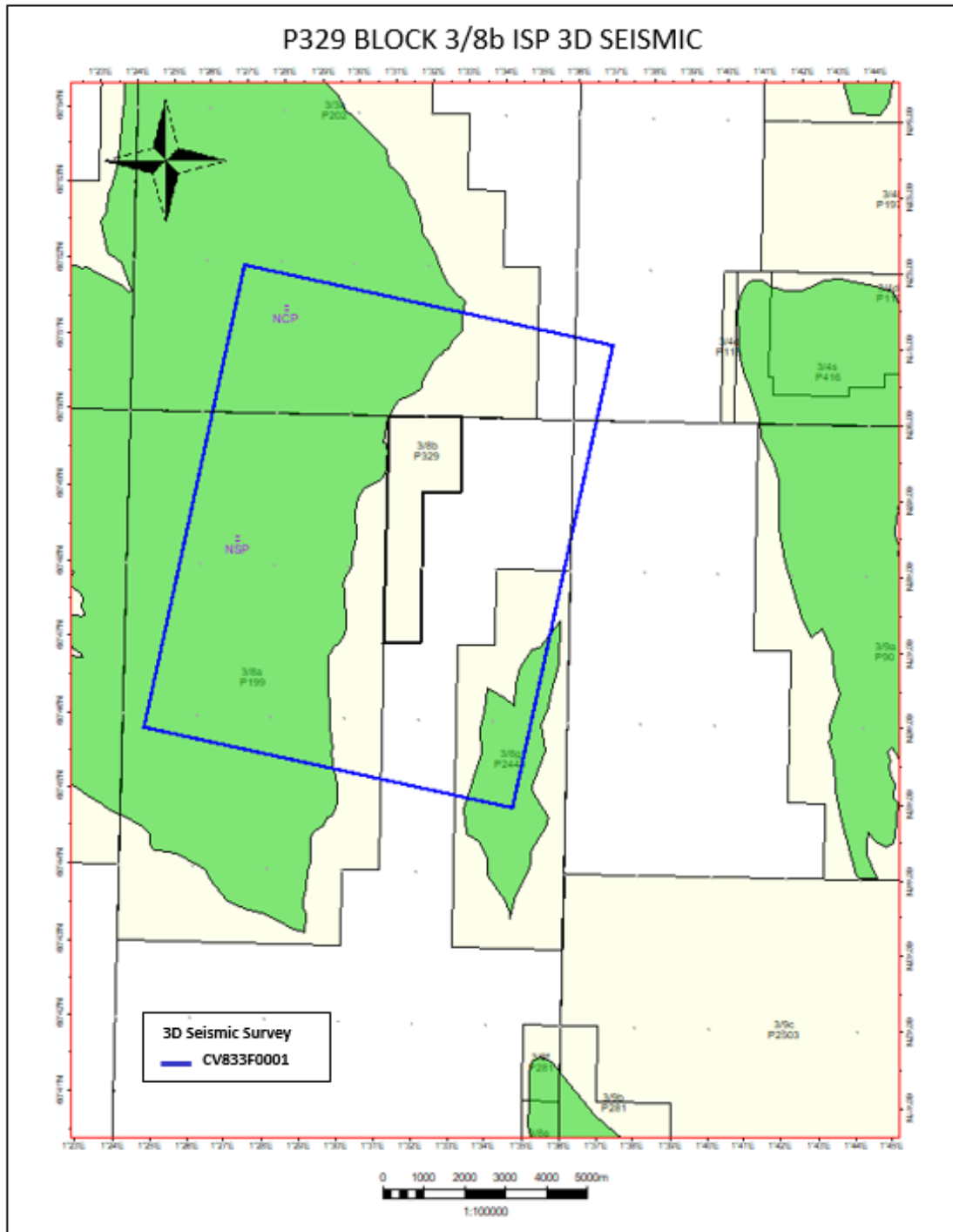


Figure 2b – 3D seismic over P329



## 5. PROSPECTIVITY UPDATE

### Staffa Field

The Staffa Oil Field lies within Licence P2448 and is well-documented by Gluyas and Hitchens 2003. Its prospectivity is considered in this document.

### Ronan

Ronan is an undrilled Upper Jurassic prospect in the hangingwall of the Ninian Boundary Fault identified by Ranger in 2000 (Appendix 1). Ninian PSDM seismic was inverted to acoustic impedance utilising 3/03- 8 and 3/08b- 11 logs. Bright impedance bodies were interpreted as sandstones in the Heather Formation. Two anomalies were mapped; a larger northern lead ('Jude', 3/3, P202); and a smaller southern lead ('Ronan', 3/3 P202 and 3/8b P329; see Figure 3). Early work proposed a second, smaller prospect named Finn but this was dropped due to high structural uncertainty.

Thin Upper Jurassic sandstones are present in Staffa wells but none occur in the Heather. Deep erosion of the Ninian footwall is evident west of Ronan in 3/08-C47 where Heather sits uncomfortably above Dunlin (Figure 4b). Progressive erosion and thinning of the Ness, Tarbert and Heather approaching the crest of Ninian indicates that the Ninian bounding fault was established and active during Heather times, so eroded Brent could have been redeposited as Heather sandstones. Reservoir presence is a critical risk, with COS estimated at 11%. STOIP evaluation was run using sums and averages from Staffa and offset exploration wells and suggested 68mmstb STOIP (Section 7).

Ranger chose to test the Upper Jurassic sandstone play at Jude to de-risk Ronan as a tie-back opportunity. Evaluation centred on the 3/03- 8 well on the southern edge of the Jude play which tested slumped Brent sandstones in the hangingwall of the Ninian fault block. This confirmed a deeper oil-water contact than Ninian and presence of slumped Brent enhanced the likelihood of an economic well, leading to sanction of the 3/03- 12 (Jude) drilled by CNR International Limited in 2003. 3/03-12 proved disappointing. It was similar to 3/03- 8 in encountering Brent slumps overlying *in-situ* Brent. However, the Heather Formation did not host sandstones and the seismic anomaly common to Jude and Ronan was concluded to identify Brent slumps rather than an as-yet undiscovered Heather sandstone unit.

Given this outcome, the Ronan prospect may represent Brent slump masses with a high likelihood of compartmentalisation and no aquifer support, and its COS was halved to 6%.

### Palaeocene

E&A wells in the East Shetland Basin typically had Palaeocene secondary targets. Dornoch and Heimdal Sandstones are present across the area but are water-bearing and normally pressured as demonstrated by dxc data in 3/03- 10 and 3/03- 11, and in 3/03-C91 RFT and log data from the Staffa wells. Whilst not prospective, they appear suitable for carbon dioxide sequestration.

### Limit of the Ninian Field

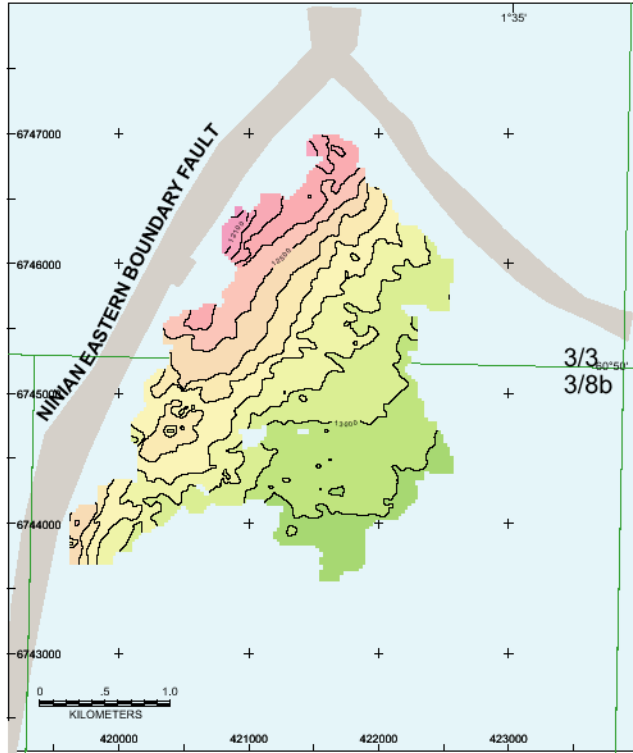
The easternmost limit of the Ninian Field lies within P199, west of P329 at the Ninian Eastern Bounding Fault (Figures 4a-e). The separation of Ninian from Staffa is apparent in seismic and also in reservoir parameters (Table 7). Staffa is deeper and gassier, and shows no pressure connection to Ninian.

Table 7 – Reservoir Properties, Ninian and Staffa.

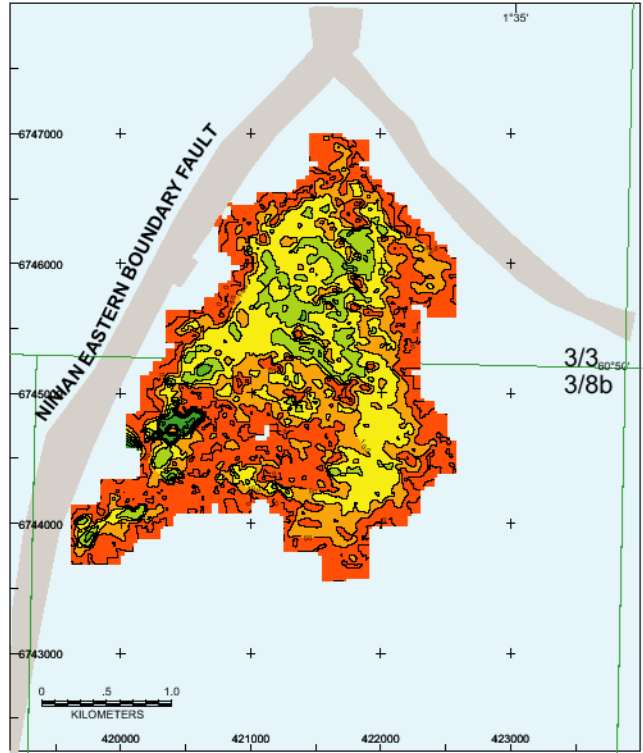
Field	OWC /ft TVDSS	Oil °API	FVF stb/rb
Ninian	-10,340	36	1.2
Staffa	-13,712	39-44	2.0

Figure 3 – Ronan Prospect Maps, Ranger (2000). Left: depth structure map at prospect top reservoir (Heather Sandstone); right: reservoir isochore

**Depth Map**



**Isochore Map**



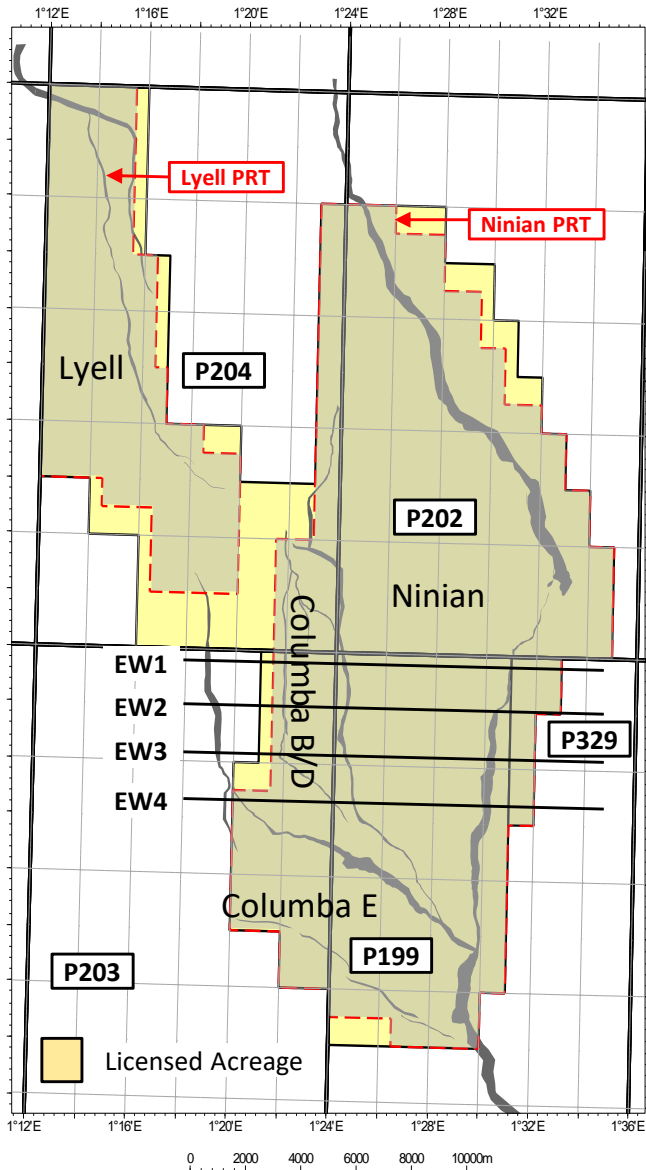


Figure 4a – Licence blocks and field outlines, Ninian area. Map shows the Ninian PRT boundary prior to redetermination in 2023. It was amended to exclude P329, following the northern and western limit of the licence area.

Green polygons show field outlines. The Ninian pool does not extend into P329 - it ends at the Ninian Boundary Fault, with Brent in the Ninian Fault block to the west juxtaposed against Kimmeridge Clay to the east.

Figures 4b-e on the following pages present a sequence of E-W seismic lines (EW1-4) to illustrate the field limit.

Figure 4b – Line EW1. ESB10 phase-shifted full-stack seismic in TWT. Interpreted horizon are: Base Cretaceous Unconformity (pale blue), Top Heather Formation (magenta), Top Brent Group (green) and Top Dunlin Formation (brown). Faults shown as dashed lines. Well tops within 50m of line projected onto section.

P329 lies in the immediate footwall of the Ninian Eastern Bounding Fault, dipping steeply to the East. Two wells were drilled close to the crest of Ninian; C90Z and C47. Both demonstrate footwall degradation through erosion, faulting and slumping, confirming that Brent reservoir is eroded at the apex of the Ninian fault block. P329 is downthrown approximately 700ms.

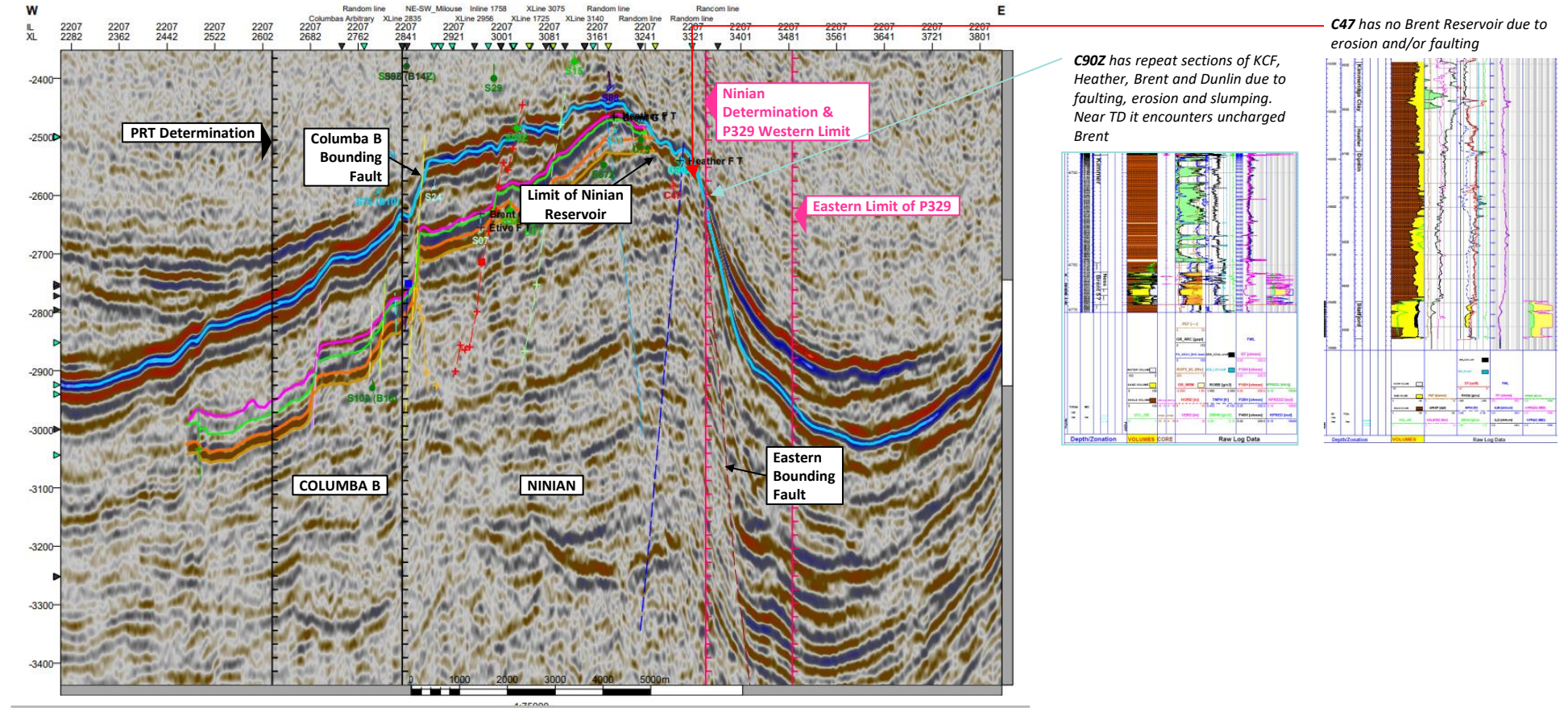


Figure 4c – Line EW2. ESB10 phase-shifted full-stack seismic in TWT. Interpreted horizon are: Base Cretaceous Unconformity (pale blue), Top Heather Formation (magenta), Top Brent Group (green) and Top Dunlin Formation (brown). Faults shown as dashed lines. Well tops within 50m of line projected onto section.

As in line EW1, steep easterly bedding dips in P329 with a throw of approximately 600ms across the Eastern Bounding Fault. The Jurassic sequence appears to be absent or significantly condensed in the western part of P329, with Cretaceous or Tertiary strata against pre-Jurassic rocks across the fault plane. To the east of the licence area, the Jurassic is at over 3s TWT and thickens eastwards.

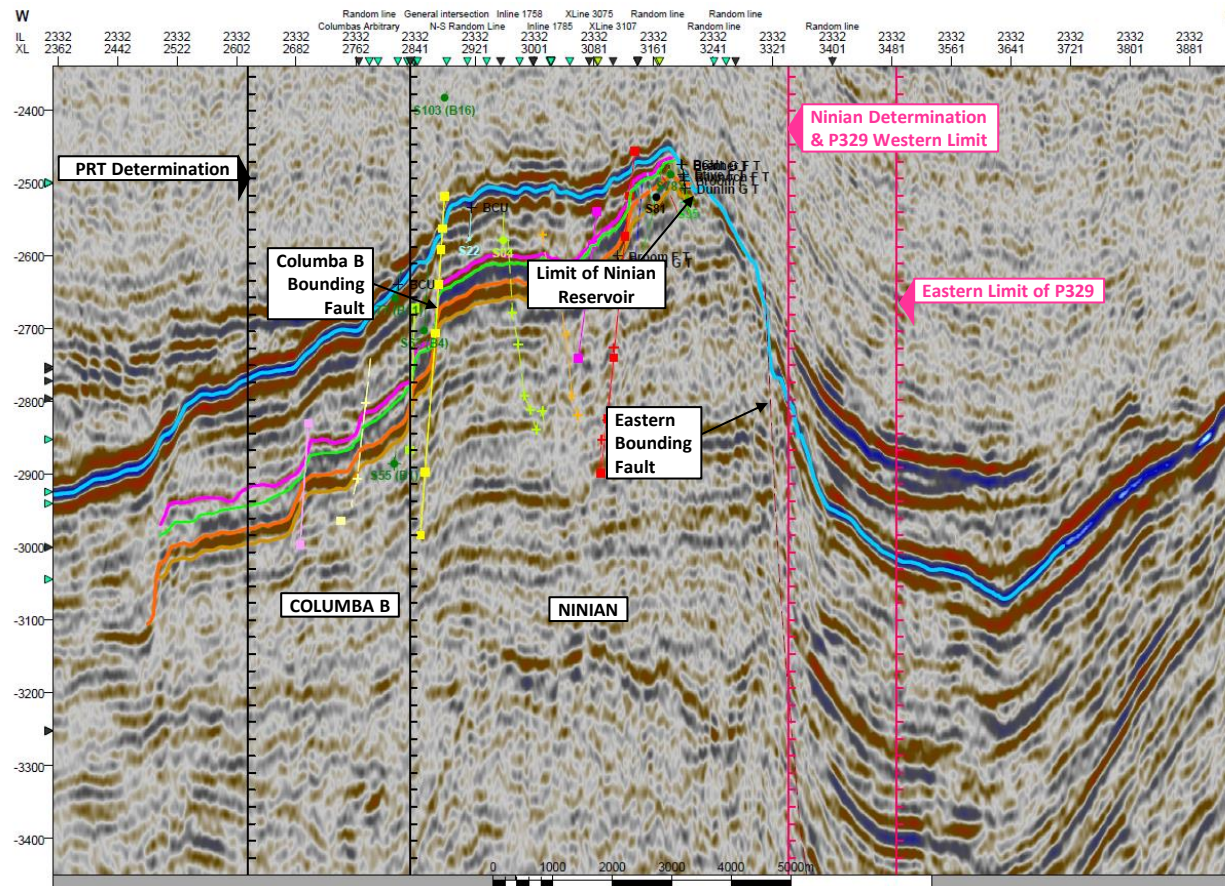


Figure 4d – Line EW3. ESB10 phase-shifted full-stack seismic in TWT. Interpreted horizon are: Base Cretaceous Unconformity (pale blue), Top Heather Formation (magenta), Top Brent Group (green) and Top Dunlin Formation (brown). Faults shown as dashed lines. Well tops within 50m of line projected onto section.

Throw approximately 600ms across the Eastern Bounding Fault. Ninian Fault Block crest denuded by erosion, slumping and faulting, providing a possible source of sand for redeposition during Heather times in the Ronan prospect. Clear separation of Mid Jurassic in Ninian from the hanging wall in the east.

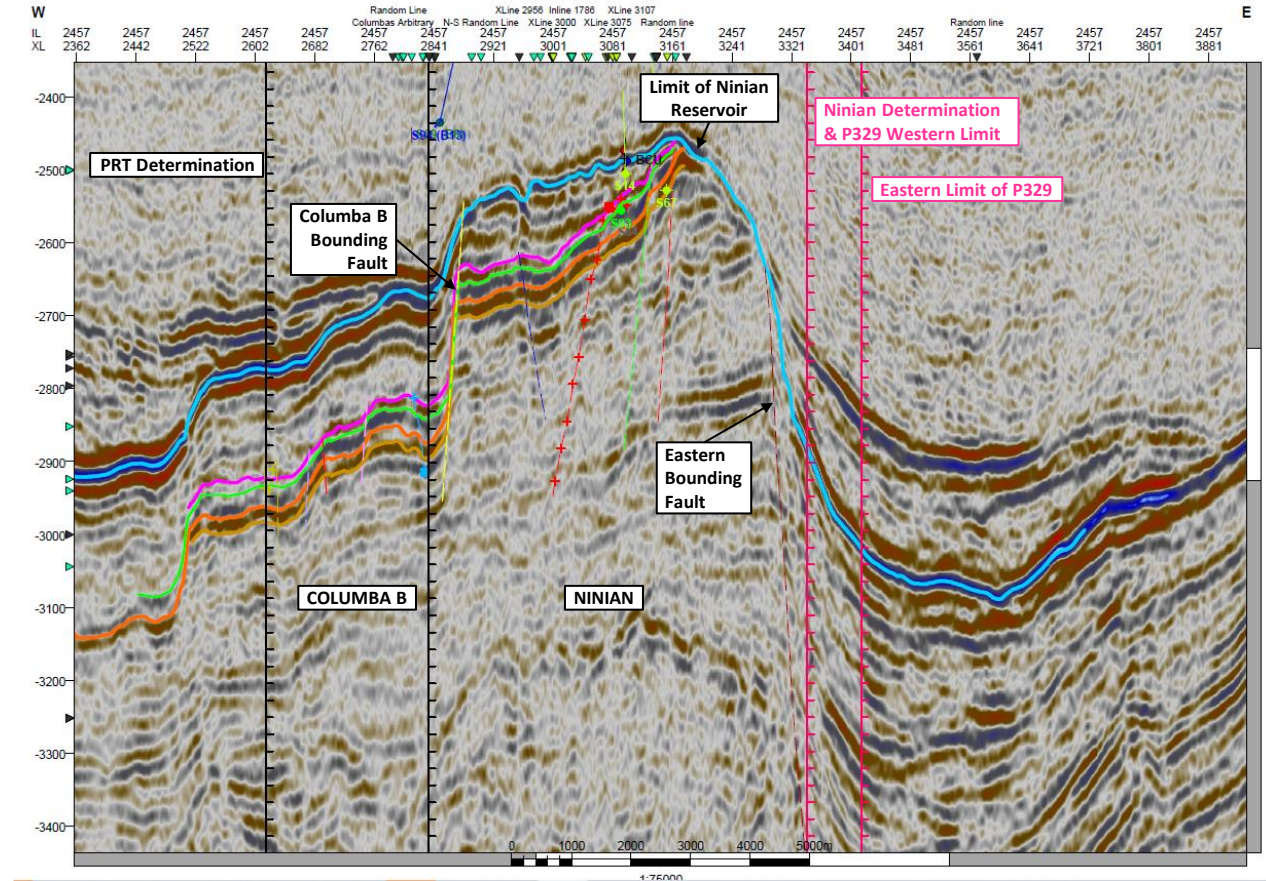
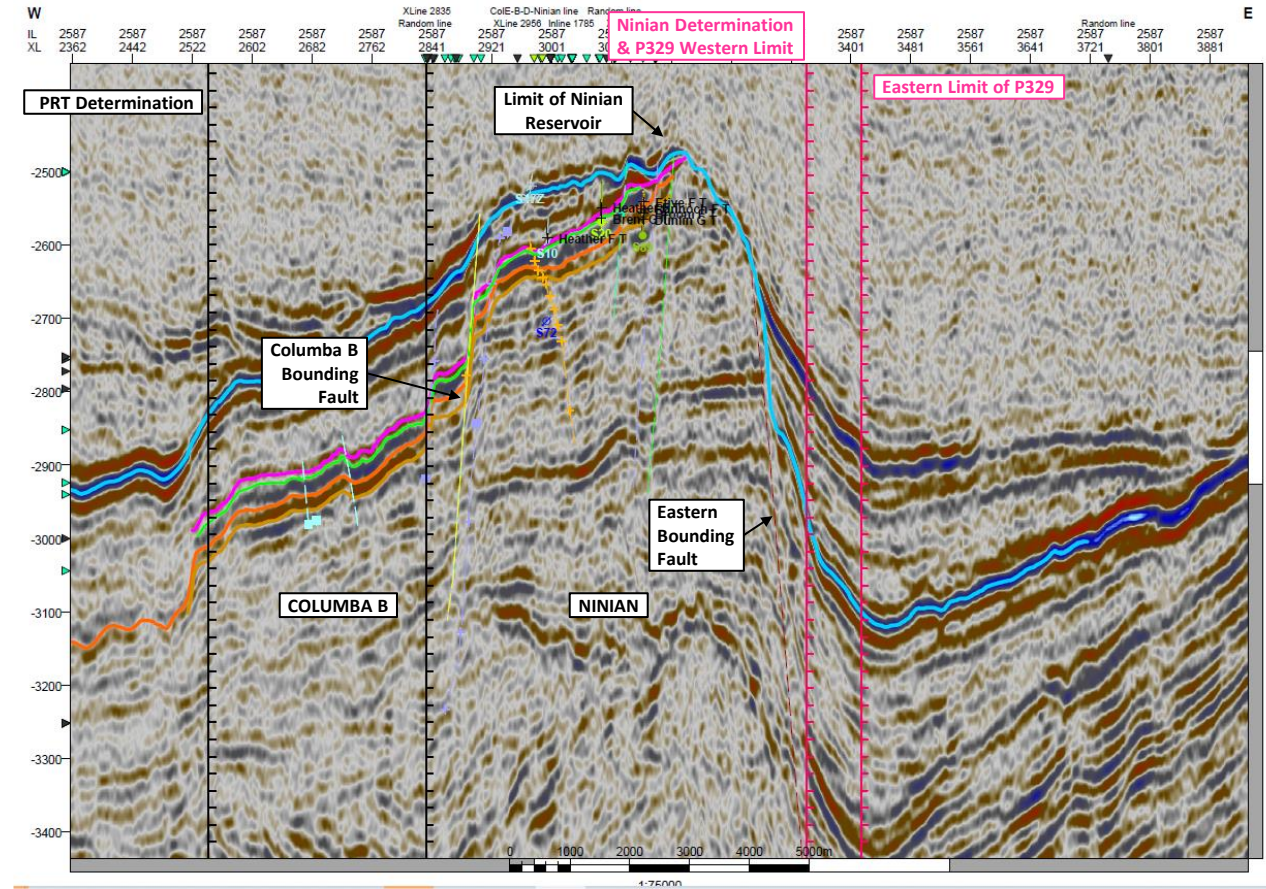


Figure 4e – Line EW4. ESB10 phase-shifted full-stack seismic in TWT. Interpreted horizon are: Base Cretaceous Unconformity (pale blue), Top Heather Formation (magenta), Top Brent Group (green) and Top Dunlin Formation (brown). Faults shown as dashed lines. Well tops within 50m of line projected onto section.

Throw approximately 700ms across the Eastern Bounding Fault. Clear separation of Mid Jurassic in Ninian from the hanging wall in the east.



## **6. FURTHER TECHNICAL WORK UNDERTAKEN**

*Dromgoole, P. & Platt, N. 2000. Prospectivity in the Ninian Hangingwall: Blocks 3/8b & 3/3. Internal Ranger study included in Appendix 1 of this report.*

## 7. RESOURCE AND RISK SUMMARY

A summary of potential remaining hydrocarbons is outlined in Table 4 below.

Table 8 – Resource and Risk Summary, P329.

Prospect/Lead/ Discovery Name	P/L/D	Stratigraphic Level	Unrisked Hydrocarbons in Place						Unrisked P50 Recoverable Resources		Geol. COS	Risky P50 HIIP
			Oil /MMbbls			Gas /Bcf			Oil MMbbl	Gas Bcf		
			P90	P50	P10	P90	P50	P10				
Ronan (3/3 & 3/8b)	P	Upper Jurassic (Heather)	44	68	97				17		6%	4
Ronan (within 3/8b)	P	Upper Jurassic (Heather)	21	33	47				8		6%	2

## **8. CONCLUSIONS: REMAINING PROSPECTIVITY**

No economic prospectivity is identified in P329 due to the small size of analogue oil accumulations in the hangingwall of the Ninian Bounding Fault, high likelihood of compartmentalisation and lack of aquifer.

## 9. CLEARANCE

CNR confirm that the NSTA is free to publish this report and that all 3rd party ownership rights on any contained data and/or interpretations have been considered and appropriately cleared for publication purposes

## 10. REFERENCES

GLUYAS, J.G. & UNDERHILL, J.R. 2003. The Staffa Field, Block 3/8b, UK North Sea. In: GLUYAS, J.G. & HITCHENS, H.M. (eds) 2003. *United Kingdom Oil and Gas Fields Commemorative Millennium Volume*. Geological Society, London, Memoir, **20**, 327-333.

## 11. Appendix 1: Prospectivity in the Ninian Hangingwall: Blocks 3/8b & 3/3

*This report predates the 3/03- 12 Jude well which did not encounter Upper Jurassic sandstones, hence reference to COS is now seen as over-optimistic. Volumetrics and risking in Section 7 take subsequent work into account.*

### Prospectivity in the Ninian Hangingwall: Blocks 3/8b & 3/3

Peter Dromgoole & Nigel Platt  
Revised 14.08.2000

#### Summary

Seismic and biostratigraphic evidence indicate that degradation of the eastern flank of Ninian took place in two main phases:

- a) Autochthonous material eroded from the Ninian fault scarp was resedimented in a hangingwall syncline to the east.
- b) Degradation of fault scarps led to formation of tectonic slide blocks draping footwall terraces.

Wells in the hangingwall syncline east of Ninian include a number of thin Upper Jurassic sandstone beds. Two sandstone packages are correlatable between wells. Independently, seismic interpretation has shown the presence of two wedge-shaped, eastward thinning units within the hangingwall syncline (Upper Jurassic 1 and 2). Seismic well ties suggest that they may broadly correlate with the degradation events mentioned above.

Lobate outlines on isopach maps and time slices, and clinoform reflectors in cross-section suggest that these sandstone packages may be submarine fan deposits derived from the Ninian fault scarp. Uncertainty exists where seismic multiples are present within the Upper Jurassic package and some sigmoidal and wedge geometries evident on seismic may result from cross-cutting of genuine and multiple events.

The 'fan' geometry and lobate pattern of thicks seen on isochore maps is consistent with submarine fan deposition, and seismic body recognition on this feature at the Upper Jurassic 2 level defines the outline of the Ronan prospect. Ronan is bounded to the east by a NNW-SSE structural lineament interpreted as the continuation of the Ninian Boundary Fault in Block 3/3. To the northwest, the feature is sealed against resedimented allochthons or the Ninian Boundary Fault. Ronan's southern limit is defined by stratigraphic pinch-out and monoclinical drape over an underlying Brent surface of terraces stepping down southwards across E-W striking faults.

The interval beneath Upper Jurassic 1 is more likely to be shale-prone than that beneath Upper Jurassic 2 as progressively deeper erosion of the Ninian crest exposed older formations with time, so whilst erosion would have affected the Brent Group initially, later erosion would have cut into the shalier Dunlin, Staffjord and Cormorant Formations. Seismic attribute analysis is consistent with the presence of sandstone reservoir.

A similar lead recognised in the southern part of Block 3/8b is referred to as Finan. The influence of seismic multiples is stronger here and the definition of Finan therefore carries a higher technical risk.

Volumetrics for Ronan and Finan suggest reserves of around 18mmbbl for Ronan (64% in Block 3/8b and 36% Block 3/3) and 24mmbbl for Finan (93% in Block 3/8b and 7% lie in open acreage in Block 3/8 to the southeast). The presence of oil in the 3/03- 8 allochthon suggests low risk of encountering gas or condensate. The lead is bounded to the southwest by a NNW-SSE fault and additional upside may be present to the south of this fault.

Ronan risk analysis gives an exploration risk of around 1 in 7 at the current state of knowledge. This has reduced from 1 in 13 due to a better understanding of fault risk (effective lateral fault seal in the nearby Columba Terraces), higher quality mapping on pre-stack depth migrated data, lithology and fluid modelling supporting the presence of reservoir facies within the Upper Jurassic and structural modelling of Upper Jurassic sediment supply. Nevertheless, reservoir presence and quality remain key risks for Ronan.

Downfaulted Brent terraces underlying Ronan are thought to include Kerr McGee's Jude prospect which lies in a down-faulted Brent terrace in Block 3/3 to the north extending across the lease line into 3/8b. Mapping of Jude suggests total mean volumetrics of 39mmbbl, of which approximately 13% lies in Block 3/8b. This is subdivided into Jude North and Jude South. Jude North lies entirely on 3/3 to the north and is regarded as the higher risk of the two, given its proximity to water-bearing autochthonous Brent section in 3/03- 8, and has mean reserves of 10 mmbbl. Jude South has mean calculated reserves of 29 mmbbl, of which around 17% (5mmbbl) lie in Block 3/8b.

Synergies may exist between Jude South and Ronan. It is possible that they could be tested by a single vertical exploration well or by sidetracks of a common deviated well from the Ninian Central Platform which lies approximately 4.7 km to the west.

## Introduction

Seismic and biostratigraphic evidence indicate that degradation of the eastern flank of the Ninian structure took place in two main phases:

- a) Autochthonous material eroded from the Ninian fault scarp was resedimented in a hangingwall syncline to the east. Well 3/03- 8 includes thick oil-bearing resedimented Brent Group intercalated with minor Dunlin Group and Heather Formation. The base of the allochthon may correspond with an Early Callovian sequence boundary within the Heather Formation. Emplacement of slide blocks is thought to have occurred during Callovian to Early Kimmeridgian sedimentation of the Heather Formation. Dipmeter evaluation indicates that the allochthon is made up of stacked slump units with differing stratigraphies. The complex pile includes Brent and older strata with the internal succession reflecting progressive downcutting and back-stepping of the degrading scarp face.
- b) Degradation of fault scarps led to the formation of tectonic slide blocks draping the footwall terraces during Kimmeridgian (and possibly later) times and was associated with only minor erosion and with more limited eastward sediment transport during deposition of the Kimmeridge Clay Formation.

Wells in the hangingwall syncline east of Ninian include a number of thin sandstone beds of Upper Jurassic age. Two sandstone packages are correlatable between wells. Independently, seismic interpretation has shown the presence of two wedge-shaped, eastward thinning units within the hangingwall syncline referred to as Upper Jurassic 1 and 2. Well ties show that these may broadly correlate with the degradation events mentioned above:

- Up to three sandstones near the top of Heather Formation of Middle Oxfordian age, possibly correlating with Upper Jurassic 2.
- Up to three sandstones within the Trent Member of the Kimmeridge Clay Formation of Early Kimmeridgian age, possibly correlating with or beneath Upper Jurassic 1.

Following a Ranger interpretation of the 3/8b prospects in October 1999, the Ninian 3D survey was reprocessed by GXT using a prestack depth migration (PSDM) approach. This included the 3/8b area and the prospectivity of 3/8b was re-examined using these new data.

PSDM data did not cover the entire Ninian 3D data area and mapping was extended using the previous Ninian 3D data so as to give an overall structural context. PSDM data covered Block 3/8b and the prospective hangingwall area of Block 3/3, therefore all prospects are mapped on the 2000 PSDM data.

## Geology

### *The Ninian and Staffa fields*

Ninian is one of the largest hydrocarbon accumulations in the UK North Sea. The field lies in the East Shetland Basin close to Brent, Cormorant, Hutton and Alwyn. Water depths range from 440-490 ft. The proven productive area covers 22,000 acres, with initial oil in place estimated at 2920 mmbbl and proven productive reserves of 1,223 mmbbl, of which 132.5 mmbbl remain to be produced.

The Ninian field was discovered in 1973-4 by wells 3/08- 1 (BP) and 3/03- 1 (Burmah), with the latter flowing 7388 bopd of 34 to 35 API oil on test. The oil has a GOR of 301 scf/bbl.

The Staffa field was discovered in 1985 by well 3/08b- 10 (TD 14 885ft). The field flowed 40-44 API oil with a high GOR (1940 scf/bbl at 3/08b- 10; 1600–2600 scf/bbl in subsequent wells) and was on production from 01.03.92 to 31.12.94. Oils were reportedly waxy with poor flow characteristics. The field had initial estimated reserves of 4.1 mmbbl (20 mmbbl STOIP) and is now depleted.

### Stratigraphy

The stratigraphy of the Ninian Field is similar to other fields in the area. Crystalline basement is unconformably overlain by Triassic continental strata. Basal lag deposits are overlain by predominantly finer-grained Triassic red beds of the Cormorant Formation. These pass gradationally up into fluvial – marginal marine deposits of the basal Jurassic Staffjord Formation which form a secondary reservoir in the Brent Field to the north but which were water-bearing where penetrated at Ninian. The Staffjord at Ninian is 50-100ft thick, much reduced from 500ft in the Brent Field. The Staffjord Formation is overlain by marine shales of the Liassic Dunlin Group.

The hydrocarbons of the Ninian Field lie in the overlying Middle Jurassic Brent Group. The reservoir section has a typical thickness of around 330ft, compared with 850ft at Brent. The uppermost unit of the Brent Group, the Tarbert Formation, is thin or absent over most of the Ninian structure, apparently due to non-deposition or erosion on the fault block crest.

The Brent Group is overlain by marine shales of the Oxfordian- Callovian Heather Group and the Kimmeridge Clay Formation of Kimmeridgian to Ryazanian age. These two units make up the Humber Group. Together with overlying Lower Cretaceous shales of the Cromer Knoll Group, these rocks form the regional seal to hydrocarbon accumulations within the Brent Group. The Heather Formation is subdivided into a lower unit of Bathonian to Middle Oxfordian age and an upper unit of Late Oxfordian to early Kimmeridgian age. The Kimmeridge Clay has high organic carbon content and forms the regional source rock throughout the Central and Northern North Sea. It is subdivided into seven subunits - from base to top these are the Trent, Ouse, Swale, Aire, Wharfe, Derwent and Mandal members.

The structure of the Ninian Field comprises a west dipping fault block and a complex horst block bounded to the east by a series of major faults making up the eastern bounding fault zone. Footwall uplift led to the development of a significant surface relief and the footwall crest of the Ninian structure was affected by tectonic and sedimentary processes during Late Jurassic times leading to the formation of a complex series of crestral slumps, slides and fault terraces on the eastern flank as this relief was degraded and eventually infilled.

The current work represents a review of the prospectivity of the Upper Jurassic section in this hangingwall to the east of the Ninian structure. Efforts have focused on integrating the biostratigraphic and seismic data. Of key importance in understanding sediment transport into the hangingwall during the Late Jurassic has been evaluation of well 3/03- 8, which includes a thick allochthonous section, interpreted as a slump block, within the Upper Jurassic succession.

### The Ninian Hangingwall - Slump Emplacement

#### Well 3/03- 8

This well, located along strike to the north of block 3/8b, encountered an apparent repetition of the Brent succession. The repeated section is oil-bearing whilst the underlying, *in-situ*, Brent does not contain hydrocarbons. The repeated section is interpreted as an allochthonous unit largely made up of redeposited Brent and Liassic material.

This unit is thought to have been shed from the footwall of the Ninian structure during Late Jurassic times. A significant amount of material was eroded from the footwall crest during Upper Jurassic rifting, although it is not clear whether any of the fault block was subaerially exposed. The diagenesis of the lower Brent deposits record dissolution of feldspar and of carbonate cement, a history which is consistent with meteoric flushing, yet overlapping of marine Upper Jurassic strata against the fault block suggests that crestral erosion may have largely taken place in a submarine environment (Underhill *et al.* 1997).

The relief and the resulting morphological instability created by footwall uplift led to scarp collapse and redeposition of a major slump block or olistolith at the 3/03- 8 location. The ages of the slump unit and of the slumping events have been the subject of some debate and are of key importance in understanding the potential of the Upper Jurassic section in downdip locations to the east. Several wells drilled in this downdip area encountered thin sandstones within the thick and otherwise monotonous Heather and Kimmeridge Clay shales (Platt & Holland 1999). A biostratigraphic study was set up in order to establish correlations between these

sections and to determine the age of the sandstones and their possible relationship with the slump unit(s) in the 3/03- 8 well. Seismic data were also reviewed for indications of reservoir development in the hangingwall.

#### *Age of the slump unit in 3/03- 8*

The slump unit lies between the Heather Formation of Early Callovian age and the Kimmeridge Clay Formation of Kimmeridgian age in this well. The unit contains fauna mostly indicative of reworked Brent Group deposits but also contains some material derived from the Heather Formation and the Dunlin Group. Geostrat (1998) do not recognise *in situ* Heather Formation above the allochthonous unit. Instead, they believe that the allochthon is overlain by shales of the Kimmeridge Clay.

Geostrat (1998) place the age of emplacement of the slump between Early Callovian and Kimmeridgian, and note that complex internal stratigraphy, with inversion of sub-units and intercalation of Heather Formation, may indicate the occurrence of several depositional episodes. The age range assigned corresponds to the entire span of the Heather Formation. Nevertheless, Geostrat (1998) venture that the base of the allochthonous unit in 3/03- 8, and by implication the onset of slumping, may correspond with the depositional sequence boundary which lies within the Heather Formation and is of earliest Early Callovian age.

#### *Slump emplacement models: Erosion degradation and/or fault scarp degradation – Ninian*

Analysis of erosion and onlap patterns on the Ninian fault block allowed Underhill *et al.* (1997) to reconstruct the evolution of the degradation complex. Underhill *et al.* recognised two distinct transport processes operating at different times:

- a) Erosion from the footwall crest, degradation of the Ninian fault crest and deposition of resedimented units (such as the 3/03- 8 allochthon) in the hangingwall syncline (Early to Middle Callovian). This age implies slumping and clastic supply into the hangingwall during Heather Formation time. According to Underhill *et al.* 1997, the eastward onlap and drape of Upper Jurassic and Lower Cretaceous sediments onto the resedimented units in well 3/03- 8 suggest that this phase of slumping was complete before deposition of the upper Heather Formation (middle Oxfordian). In contrast, Geostrat (1998) do not recognise *in situ* Heather Formation above the top of the allochthonous unit, inferring that the slumping represented by the allochthonous unit in 3/03- 8 could have taken place, or continued, slightly later (between the Early Callovian and Early Kimmeridgian);
- b) Fault scarp degradation leading to the formation of slide blocks draping fault terraces of the footwall (Early Kimmeridgian). These slide blocks, although displaced, contain evidence of internal Brent Group stratigraphy and appear more or less intact. This suggests more limited sediment transport into the hangingwall at this time. Analysis of this upper degradation complex reveals strong variation downdip. Westerly areas are characterised by coherent blocks of semi-autochthonous Brent Group, whilst easterly, downdip areas show poorer reservoir quality and are marked by disaggregated sediment.

Underhill *et al.* note that onlap and complete burial of the degradation complex and underlying Brent Group deposits may not finally have been achieved until the end of the Jurassic or even into the Cretaceous (as reported from the Visund Field of Norway by Alhilali and Damuth 1987; Faereth *et al.* 1995). This history of gradual burial of the Ninian structure implies that there would have been potential for limited erosion and re-deposition of clastics from the Ninian fault block throughout Kimmeridge Clay Formation and possibly even into Cromer Knoll Formation time.

#### *Slump emplacement analogues: Laterally continuous slide units – Brent Field; Multi-phase, multi-level history – Staffjord Field*

Some similarities to the Upper Jurassic erosion and deposition histories on and around the Ninian structure may be provided by the areas around the Brent and Staffjord fields (Coutts *et al.* 1996; Hesthammer 1999).

A degradation complex is developed at Brent, forming a north-south oriented, linear series of slump units which moved along listric faults soling out in the shales of the underlying Dunlin Group. Seismic lines across the Brent structure show that the slump units form an imbricate stack of fault slices with relatively little displacement which may even permit the construction of balanced cross-sections in some instances. These slump units appear most similar to the footwall degradation complex at Ninian described by Underhill *et al.* (1997). However, evidence

for good communication and pressure connectivity between the slump units in the Brent Field suggests that they have remained mostly intact with rather more limited sedimentary transport than that which took place at Ninian.

The most likely explanation for the different style of the slump units in the two areas lies in the greater thickness of the Brent Group at Brent in comparison with Ninian (800ft vs 350ft) as well as the relatively sandier section in the Brent Field. A thicker, sandier Brent section may have experienced lesser internal deformation and re-sedimentation than the thinner section at Ninian, where the interbedded and underlying shale sections may have offered more potential for décollement and internal disruption of the Brent Group deposits.

Studies of analogous, highly complex slump features in the Staffjord Field (Hesthammer and Fossen 1999) indicate a more complex slump history. Several stages of slumping have occurred with deepening of the detachment level over time and back-stepping of new scarp faces created in each case. Initial failure occurred in the upper part of the Brent Group, with detachment within shales of the Ness Formation. Next, slumping cut into the Liassic, detaching within shales in the lower part of the Dunlin Group. The new scarp created behind the Dunlin slump was then affected by further high-level Brent slumping. This was followed by further, deeper detachment within the Staffjord Formation with slip occurring this time within shales at the base of the unit. Once again, further slip of Brent and Dunlin strata then took place on the new scarp face created in the Brent and Dunlin groups.

This multi-phase, multi-level slump history has led to a very complex stacking of slump units in the hangingwall of the Staffjord Field. Similar emplacement mechanisms appear likely to explain the complex internal stratigraphy recognised in the 3/03- 8 allochthon by Geostat (1998).

#### *Appearance of 3/03- 8 slump on seismic data*

The 3/03- 8 well lies close in to the Ninian Boundary Fault. Imaging is imperfect and well interpretation is not straightforward. Irregular reflections in the Upper Jurassic interval could be interpreted as mounding associated with slumping, although no internal structure is discernible within the allochthon and its lateral extent is uncertain. An alternative interpretation of reverse faulting cannot be excluded. It should be noted, however, that simple structural repetition of the Brent succession cannot adequately explain the biostratigraphic evidence discussed below, which records complex reversals of biostratigraphic indicators apparently consistent with episodic reworking and/or chaotic slump folding rather than reverse faulting.

#### *Analysis of 3/03- 8 slump from dipmeter and biostratigraphy*

Dipmeter logs confirm this hypothesis. The dipmeter data are generally good quality and when presented alongside biostratigraphic occurrence data, permit comparison of dip data with the age dating.

The regional dip is clearly identifiable within both the underlying autochthonous Brent Group and the overlying Kimmeridge Clay Formation. Between these two intervals, the allochthonous unit displays a range of different dips suggesting the presence of rotated and back-rotated blocks. Several chaotic intervals are identified and some of these may be associated with zones displaying sharp vertical changes in dip which are interpreted as individual slump planes.

Reconciliation of dip and biostratigraphic data suggests the development of a complex stack of slump units riding one on top of another. Biostratigraphic markers are relatively sparse and present over only a part of the full allochthon thickness, so that full reconstruction of slump emplacement history is very difficult. Nevertheless, it is apparent that the allochthon comprises a thick and complex stack of slump units with differing stratigraphies.

The thinner slices comprise upper Brent Group deposits, mainly Ness Formation sandstones. Possible presence of Tarbert Formation within the topmost slump of the allochthon points to the presence of Tarbert Formation deposits on the Ninian footwall crest prior to erosional truncation. The absence of Tarbert Formation deposits over the Ninian footwall crest may therefore reflect removal through slumping rather than non-deposition. The thin slices of upper Brent deposits were probably detached on Rannoch Formation shales of the lower Brent Group. A thicker slump unit present in the middle part of the allochthon comprises older shales at the base passing up into overlying Brent deposits which presumably rode 'piggyback' above a detachment surface within the Dunlin Group shales.

This vertical succession is entirely consistent with the model presented above for slump emplacement in the Stafford Field, with the composition of stacked slump units reflecting a complex history of down-cutting and back-stepping of the scarp face.

It seems clear that slump emplacement took place over a significant period which embraced much of Heather Formation time since the slump units are stacked together with intercalated intervals of Heather Formation deposits. Although it is possible that these shales may themselves have been transported into position following sliding off the footwall crest, it appears much more likely that they record in situ background sedimentation which took place between the repeated and episodic emplacement of the individual slump units.

## The Ninian Hangingwall – Upper Jurassic Sandstones

### *Biostratigraphic correlation*

Biostratigraphic analysis of wells to the east of Ninian (Geostrat 1998) allows correlation of the Heather and Kimmeridge Clay formations and permits stratigraphic comparison of the sandstone units present (Platt & Holland 1999). The wells analysed, with the exception of 3/03- 8, all lie more than 5 km from the Ninian Eastern Boundary Fault. Sandstone units are identified from mud-log descriptions and from well logs, notably from low gamma ray responses. Several of the sandstones display an identifiable resistivity peak. Sonic spikes associated with the sandstones may indicate either cemented sandstones (low porosity) or could point to the presence of limestones rather than sandstones.

The sandstone units identified in the wells are thin (typically 10' or less). This would be consistent with deposition in a distal setting at some distance downdip from the Ninian fault block. Erosion (or degradation) of the footwall crest is clearly identifiable on seismic, indicating that the Ninian fault block formed a sediment source at this time.

Sandstone units occur at several different horizons:

### *Top allochthonous unit*

Three sandstones occur below the base of the Kimmeridge Clay (Trent Member) in 3/03- 8. The uppermost sandstone is around 15ft thick. These sandstones were previously assigned to the top of the Heather Formation (see b) below). However, recent biostratigraphy (Geostrat 1998) does not recognise *in situ* Heather Formation above the slumped unit and instead assigns these sandstones to the top of the reworked, allochthonous unit.

### *Near top Heather Formation (sensu stricto)*

Three thin sandstones occur in 3/08b- 10 towards the top of the Heather Formation (*sensu stricto*) between the LJ1 *lamberti* (J46) and LJ2 *glosense* (J54) maximum flooding surfaces, placing this event as Early to Middle Oxfordian. The upper one appears to correlate with a thin sandstone unit present beneath the J54 *glosense* maximum flooding surface in 3/08b- 13 and 3/08b- 11, a correlation dating this unit as of Middle Oxfordian age.

A single thin sandstone also occurs in 3/8b- 10, below the LJ1 *lamberti* (J46) maximum flooding surface. This sandstone is therefore dated as Middle to Late Callovian.

### *Near top Heather Formation (sensu lato)*

A single thin sandstone in well 3/03- 11 is assigned to the Heather Formation (*sensu lato*) with the biostratigraphic data (Geostrat 1998) indicating a horizon just above the LJ3 *rosenkrantzi* maximum flooding surface and between the J54 and J62 markers. This corresponds with the latest Late Oxfordian.

### *Kimmeridge Clay Formation (near top Trent Member)*

Three thin sandstones occur within the Trent Member below the LJ4 *eudoxus* maximum flooding surface of well 3/8b-10, giving a middle Early Kimmeridgian age. These three sandstones appear to correlate with three

sandstones at the same horizon in 3/08b- 13. The upper of these sandstones may also correlate with a single thin sandstone in 3/08b- 11.

*Kimmeridge Clay Formation (Swale Member and Aire Member)*

A single thin sandstone occurs in the Swale Member below the LJ5 *hudlestoni* maximum flooding surface in 3/03- 8, placing this as late Middle Kimmeridgian in age. A further thin sandstone occurs within the Aire Member of the same well.

Consideration of the ages and occurrences of the sandstone units above indicates that the principal horizons with sandstone beds which are potentially correlatable are: *Top Heather Formation (sensu stricto)* - Middle Oxfordian, and *near top Trent Member* - Early Kimmeridgian.

*Seismic correlation of intra – Upper Jurassic reflectors*

Previous studies (Curtis 1996; Henderson 1996; Ranger 1997) have recognised a range of features within the Upper Jurassic section to the east of Ninian. Wedge geometries with positive relief and prominent downlap (toelap) have been interpreted as evidence for the presence of submarine fans in the Ninian hangingwall.

*Well ties*

The confidence of the seismic picks is moderate. There are multiples, and several interpretation possibilities exist. Suggested ties are as follows:

Well	Event	Equivalent Biostratigraphic Pick	Formation
3/03-8	UJ2	Horizon picked, difficult to correlate with 3/3-11	intra Trent Member
3/03- 11	UJ2	Jump correlation outside 3D volume LJ2	
3/08b-10	UJ2	LJ2 to LJ3	top Heather Fm s.s. to near top Heather Fm s.l.
3/08b-11	UJ2	LJ2 to LJ3	top Heather Fm s.s. to near top Heather Fm s.l.
		LJ2 (from 3/3-8)	top Heather Fm s.s.
3/08b-13	UJ2	LJ2	top Heather Fm s.s.

This interpretation is consistent with a correlation of UJ2 with the sandstones developed near the top of the Heather Formation *sensu stricto* in 3/08b- 10, 3/8b- 11 and 3/08b- 13.

*Hangingwall sediment supply and erosion of the Ninian fault block*

The Ninian fault block is the most likely local source of clastic material within the Upper Jurassic to the east of the Ninian field, with sediment supply coming from erosion of the footwall crest. There is clear seismic evidence for erosion or degradation of the Brent Group at Ninian, with down-cutting through the underlying formations, possibly as deep as the basement. The timing and extent of erosion is likely to be of importance in determining the lithology and reservoir potential of resedimented units. Thus units deposited from erosion of the Brent Group are likely to be good quality, clean reservoirs. However, the presence of fan or mounded geometry within the Upper Jurassic does not necessarily indicate the presence of good quality reservoir since deeper erosion would see removal and reworking of a mixed section of sandstones and shales within the Dunlin, Stafford and Cormorant units and may potentially have been associated with sedimentation of shalier clastics in the Ninian hangingwall. In this case any intercalated clastic horizons may be expected to be thinner, with poorer lateral and vertical continuity and with poorer reservoir characteristics.

In contrast, in Block 3/8c to the south, Ranger studies, as well as earlier work by BP reported in the Ranger farm-in file, show that the Brent Group is not eroded and was never exposed at the 3/08c- 12 location. This would imply that any Upper Jurassic wedge in the extreme south of Block 3/8 is unlikely to be sand-prone.

Reservoir presence and quality therefore remains a key risk affecting this play and an understanding of the age of erosive down-cutting and the relationship between erosion and sedimentation is therefore of key importance. The likely sand source area was from erosion at the footwall crest of the Ninian structure and it is important to determine whether, and when, erosion of the footwall took place.

Although essentially a west-dipping fault block, the Ninian structure is traversed by a number of NW-SE faults. These cross-faults are visible on the base Cretaceous surface and define the edges of the Columba terraces as well as of the crestal horst block. It is likely that the cross-faults acted as sediment input paths for material eroded from the Ninian fault. Sediment input along cross-faults would have greatly increased the volume of clastics which could have been transported eastwards, since structural dip during Late Jurassic times was otherwise predominantly from east to west. The source area for clastic input into the syncline to the east would otherwise have been confined to the fault scarp itself. Maps of the top Brent surface were examined closely for the presence of channels located along these cross-faults. However, it has not been possible to positively identify channels along or away from these faults.

A short structural study was carried out with the aim of assessing the structural controls on sediment supply (Alastair Beach Associates 2000). Some of the key conclusions are outlined below:

- Mapping of slumps in the footwall suggests that in the southern part of the Ninian Central Horst the transport direction is to the southeast, and in the northern part of the Southern Flank the transport direction is to the east. This gives support to the location of the distal fan bodies mapped at Ronan and Finan.
- Degradation of the footwall is greater on the southern part of the Central Horst and the northernmost part of the Southern Flank compared to the rest of the Southern Flank. This is also in agreement with the geometry of the Ronan body which is thickest in the north and thins to the south and southeast. This implies that the Ronan fan could primarily have been sourced from the southern part of the Horst.
- Footwall degradation of both the Brent Group and the Stafford Formation provide potential sand sources.
- The area of lower throw on the Ninian Boundary Fault close to the updip closure of the Ronan fan may have been a sediment transport pathway.
- The volumes of the potential sand transported to the footwall are large and the same order of magnitude as the Ronan prospect.

#### *Fault seal*

Alastair Beach Associates 2000 report also looked into the updip closure of hangingwall fans in Block 3/8b. The key conclusion was that the Ninian Boundary Fault should provide a good seal for hydrocarbons since a fault of this size is expected to have a significant damage zone. This assessment is supported by regional evidence from the Columbas, where sealing across seismic-scale faults is well-documented.

### **The Ninian Hangingwall – Geophysical Studies**

#### *Mapping and Depth Conversion*

Four horizons were mapped over 3/8b: Base Cretaceous, Upper Jurassic 2, Top Brent and Top Dunlin. Mid Triassic and Basement were mapped over the Ninian Horst and East Flank areas. The Ninian eastern boundary fault and the fault bounding the horst block to the west were remapped to ensure a consistent fault pattern for the interpreted horizons. In all cases the horizons picked on the PSDM data were then merged with horizons picked on the previous Ninian 3D data to provide a more extensive mapped area.

#### *Base Cretaceous*

The Base Cretaceous Unconformity was picked on the Ninian PSDM data. This was then merged with the previous BCU interpretation and data exported to Zmap. This shows the main structural features of the Ninian field, Eastern Boundary Fault (EBF), the deep syncline of the Ninian hangingwall and the slightly higher area of the Staffa field (3/08b- 10, 11, 13, 14 & 14Z).

#### *Upper Jurassic Event 2*

Using the previously mapped UJ2 horizon as a guide this horizon was reinterpreted over the area and extended to the north. It is tied into the 3/8b wells in the south and corresponds to the LJ2 MFS: J63 geological pick. Correlation to the north is not definitive, however the event can be tied to the Intra Trent Member Depositional SB geological pick in well 3/03- 8 which corresponds to the uppermost sand at the top of the Allochthonous unit in that well. It also correlates to the LJ2 MFS pick in well 3/03- 11. This horizon was not depth converted.

Structural closure against the Ninian EBF exists at this level with well 3/03- 8 about at the spill point and the structure extending into Block 3/08b.

*Top Brent and Top Dunlin*

The previous Top Brent pick was used as a guide and remapped carefully to tie all the 3/8 and 3/3 wells in the hangingwall. It is of reasonable quality but affected by faulting to the east of the syncline which makes correlation to 3/03- 11 and 3/04b- 17 difficult. Top Dunlin was mapped over the same area. These maps show similar structural features to both the Base Cretaceous and Upper Jurassic 2 horizons. The closure against the Ninian EBF is seen on both maps – Kerr McGee identify this as the ‘Jude’ prospect.

Average velocities to Top Brent were calculated for wells in the hanging wall and are shown in the table below.

	Horizon	Seismic Horizon name	Horizon time	Velocity log time	Diff Hor-Vel log	TD curve	Diff Hor-TD curve	Av. Velocity Horizon time	Depth
N27	Top Brent	Zap_PWD_EF_tbrnt.	3180		-	3150	30.00	8117.14	12906.25
3/3- 8	Top Brent	Zap_PWD_EF_tbrnt.	3140	3125	15.00	3140	0.00	8172.92	12831.48
3/3- 11	Top Brent	Zap_PWD_EF_tbrnt.	2890				-	7956.90	11497.72
3/8b- 10	Top Brent	Zap_PWD_EF_tbrnt.	3226	3212	14.00	3223.5	2.50	8179.23	13193.09
3/8b- 11	Top Brent	Zap_PWD_EF_tbrnt.	3216	3234	-18.40	3226	-9.50	8239.76	13249.54
3/8b- 13	Top Brent	Zap_PWD_EF_tbrnt.	3290	3281	9.00	3287	3.00	8267.76	13600.46
3/8b- 14z	Top Brent	Zap_PWD_EF_tbrnt.	3222	3204	18.00	3211	11.00	8151.83	13132.60
3/8b- 14	Top Brent	Zap_PWD_EF_tbrnt.	3260	3213	47.00	3232	28.00	8215.95	13392.00

The Staffa wells in the south tended to have a distribution of velocities and N27 is a highly deviated well. Using just 3/03- 8, 3/08b- 11 and 3/03- 11 and the map times from Zmap gave a much better velocity-time trend. This velocity function produced a Top Brent depth that tied 3/03- 8 and would produce a more correct depth map for volumetric calculations for Jude. Consequently the function derived from these three wells was used to depth convert the Top Brent time map using Zmap.

This velocity function ( $V=0.8448\text{Time} + 5532$ ) was used to convert the Brent time map to depth.

*Ronan and Finan mapping*

Seismic data were sent to IKODA for volume mapping using VolumeFinder, an IKODA software product which searches and extracts connected bodies within the seismic cube. It can work on both seismic and acoustic impedance data; and for this study IKODA inverted the seismic cube to impedance. A threshold value is set, and VolumeFinder examines the whole dataset for connected objects within that threshold limit. This can be carried out on 6 or 26 way connectivity criteria; 6 way was used in this case to contain the body. The characteristics of the body are then determined in VoxelGeo and the values output in a table. With a user-defined interval velocity, volumes are calculated.

IKODA also carried out a full petrophysical analysis and modelling study to examine the characteristics of these mapped bodies. This showed that bodies mapped within the Heather below the Upper Jurassic 2 seismic horizon had an AI value most likely to be sand. Horizons representing the top and base of these bodies were brought into Seisworks and mapped, and taken into Zmap for depth conversion and volumetric calculations.

The velocity function used to produce the Top Brent depth map was also used to convert the Ronan and Finan time surfaces to depth.

For the isochore, the time interval was converted to thickness using an interval velocity of 14,000 ft/sec. This velocity agrees with both the IKODA AI work and the velocity seen in the well 3/8b wells for this interval.

### *Mid Triassic and Basement*

The Triassic and Basement had not previously been mapped over Ninian. This interpretation only covers an area adjacent to the Ninian Eastern Boundary fault and is tied into well 3/03- 4 – the only well to penetrate these units in the field. Mapping allows an understanding of juxtaposition of hangingwall against footwall stratigraphy and shows that Upper Jurassic 2 would juxtapose the Mid Triassic event in the footwall.

### *3/03- 8 well analysis*

The 3/03- 8 well has a thick allochthonous unit with a 15ft sand at the top. The synthetic seismic response from this unit is minor. However, if sonic and density logs are edited to insert a sand body some 200ft thick, a significant seismic event is produced. An event similar to this in terms of polarity and strength is seen in the interval between Upper Jurassic 2 and Top Brent further south and has been evaluated as the Ronan prospect.

## **Upper Jurassic Prospect Evaluation**

Isochrons between the BCU and Upper Jurassic 2 and Top Brent show possible depositional trends in the footwall and are described below together with a potential prospect in the lower interval.

### *BCU to Upper Jurassic 2*

This shows a predominant thick in the area of the footwall to the north of 3/03- 8. The section thins rapidly to the northeast towards the high area around 3/03- 11 and 3/04b- 17. It is also relatively thin to the south of 3/03- 8 but thickens again into the low to the east of 3/08a- 8. It is thin over the prospect described below.

### *Upper Jurassic 2 to Top Brent*

In this interval the thickest part is seen in the syncline to the south of 3/08a- 8. It remains thick further north over the area of the mapped prospect but is relatively thin in the footwall area around 3/03- 8.

### *Upper Jurassic prospects – Ronan and Finan*

REP Volumetrics for Ronan indicate reserves of approximately 18 mmbbl, of which 64% lie on 3/8b and 36% on 3/3 to the north. REP Volumetrics for Finan indicate reserves of approximately 24mmbbl, 93% of which lie on Block 3/8b and 7% of which lie on the open portion of block 3/8 to the southeast.

## **Jude Prospect evaluation**

The Jude prospect as defined by Kerr McGee is a Brent stratigraphic closure against the Ninian EBF. The spill point of this is defined by well 3/03- 8 which is deemed to have drilled just below the OWC at Brent level. The Top Brent depth map shows a structure which could have a spill point at about 12,830ft TVDSS. A map of the Brent isochore above this level was produced and volumetrics calculated for the Jude North prospect. The Jude structure to the south is shown to close at the 13100ft TVDSS contour against the continuation of the Ninian horst boundary fault to the southeast and this spill point has been used to define the Jude South prospect.

Volumetrics were calculated for Blocks 3/3, 3/8b and 3/8a using petrophysical parameters derived from 3/03- 8. The data showed an *in situ* Upper Brent (faulted base) section from 12944-13688ft with a gross thickness of 747ft, net sand thickness of 460ft giving a Net/Gross of 62%. Porosity ranged from 11-15%, most likely 14%. Typical Sw for oil bearing Upper Brent is 30% with a range of 20-50%. A FVF of 1.5 with a range of 1.2 to 1.6 was deemed appropriate from Columba field analogies.

REP volumetrics for Jude North and Jude South show that Jude could contain around 157mmbbls STOIPP of which approximately 13% lies in Block 3/8b. Jude is divided into two, separated by a fault extending southeast as an extension of the Ninian Eastern Boundary Fault. Jude North lies entirely on 3/3 to the north and is regarded as the higher risk of the two, given its proximity to the water-bearing autochthonous Brent section in 3/03- 8, and has mean reserves of 10mmbbl. This represents an absolute maximum figure since it assumes the deepest possible depth for OWC which is still consistent with the presence of water-bearing Brent in 3/03- 8. A

higher OWC would give progressive reduction of reserves. Mapping assumes a deeper OWC for Jude South, which has mean reserves of 29mmmbbl, with around 17% (5mmmbbl reserves) of this lying on Block 3/8b.



It is possible that both Jude South and Ronan could be tested efficiently together, either by a single vertical exploration well, or by high angle sidetracks drilled from a single deviated well originated from the Ninian Central Platform which lies approximately 5 km to the west.

## Risking

1. Source rock presence and effectiveness offer a low risk with regional presence and effectiveness of Kimmeridge Clay shales documented throughout the area.
2. Downward migration from Kimmeridge Clay to the near top Heather Formation is required – this is perceived as offering a low risk.
3. Reservoir presence, quality and thickness is a key risk. AVO and conventional seismic attribute analysis are of limited use at this depth and no success has been achieved with seismic coherency studies. Mitigation of this risk is offered through seismic inversion to acoustic impedance nevertheless.
4. The trap is defined on 3D seismic but has an updip seal against the Ninian Eastern Boundary Fault. Fault offset presents the possibility of juxtaposition against clastics of the Brent / Statfjord / Cormorant formations. Initial review of the fault surface and fault seal predictions have helped to mitigate this risk. Additional encouragement here comes from positive evidence and experience of effective regional fault seal in the Columba area.
5. Although associated gas is expected to be present with the oil, the risk of encountering gas or condensate alone is believed to be low. There is a significant lateral variation in oil maturity in Ninian and Columba. This may reflect sourcing of hydrocarbons from both the west (shallower kitchen, heavier, less gassy oils) as well as from the east across the Ninian Boundary Fault (deeper kitchen, lighter gassier oils at Columba E for example). Likewise, Alwyn may be sourced from an adjacent, deeper gas condensate kitchen across the next major fault system to the east. On the eastern side of Ninian and in the area of interest, the 3/03- 8 allochthon contains 30°API oil. At greater depths, the Staffa field encountered 40-44°API light crudes with a high GOR (1940 scf/bbl) at a reservoir depth of 13 037ft TVDSS and reservoir temperature of 110°C.

It is anticipated that oil accumulations in the Upper Jurassic of the Ninian hangingwall will lie under conditions and thermal maturities ranging between those in the 3/03- 8 allochthon and those at Staffa. The Ninian facilities rely on produced gas for energy generation. Whilst surplus gas presents a flaring problem at the present, lower gas volumes will be produced from Ninian and Columba in the future. This may result in a gas requirement to power the Ninian facilities which may permit the use of produced gas.

A modified risking form (overleaf) shows estimates of risk from April 1999 and August 2000, showing how the risking assessment evolved through technical work on seismic mapping or seismic reservoir and fluid prediction as well as on structural aspects surrounding updip fault seal and Upper Jurassic sediment supply. The present analysis gives a risk of around 1 in 7 at the current state of knowledge.

<u>Ranger Oil Probability of Technical Success</u>					
Country: UK		Evaluated by: NHP			
Licence/Block: P. 329 3/8b (Ranger 100%); P.202 3/3 (Ranger 0%)		Date: 14.04.99			
Prospect: Upper Jurassic - Ronan		Update: 10.08.00			
Parameter	Comment	Probability (0.3-1.0)		Apr-99	Aug-00
after further work					
<b>Trap Geometry</b>	Upper Jurassic Event 2 imaged on 1998 reprocessed 3D seismic Significant multiple contamination hinders reliable interpretation of basal contact and distal pinch-out Combined stratigraphic / structural trap Aug 2000 - mapped on acoustic impedance volume, improved depth conversion - isochore map reveals distinctive fan geometry	Total P (trap)	0.70	0.90	
			0.70	0.70	
			<b>0.49</b>	<b>0.63</b>	
<b>Reservoir Presence and Effectiveness</b>	Thin Upper Jurassic sandstones present in Staffa wells. Presence of submarine fan deposits is likely from sedimentary model and from proximity to source area (Ninian fault block) - play untested locally or regionally Reservoir quality unknown - erosion of JL, Triassic -> more shale-prone Aug 00 - acoustic impedance model supports sand presence - structural and erosion models support sand delivery, sand volume	Total P (reservoir)	0.50	0.70	
			0.50	0.50	
			<b>0.25</b>	<b>0.35</b>	
<b>Source Presence and Effectiveness</b>	Upper Jurassic Kimmeridge Clay Formation regionally present & proven. Downward migration required from KCF Clay to near top Heather Fm - low risk Light crudes with high GOR in nearby Staffa Field Aug 00 - unchanged	Total P (source)	1.00	1.00	
			1.00	<b>1.00</b>	
			<b>1.00</b>	<b>1.00</b>	
<b>Seal Presence and Effectiveness</b>	Top seal from overlying pile of Kimmeridge Clay Fm & Cromer Knoll Gp. Columbas provide ample evidence of regional fault seals. Updip fault seal against Ninian EBF Aug 00 - updip stratigraphic seal locally against KCF/ Heather - elsewhere updip stratigraphic seal against allochthon deposits - (proven oil-bearing in 3/3-8, low connectivity / low flow rates) - new work by ABA assigns lower risk on fault seal even where reservoir juxtaposed against Brent /Stafford /Cormorant clastics	Presence (G)	1.00	1.00	
			Effectiveness (H)	0.50	0.70
		Total P(seal) =G x H		<b>0.50</b>	<b>0.70</b>
<b>Critical Risk</b>		<b>Probability of Technical Success</b>			
Key risks : Reservoir presence and effectiveness		=P(trap) x P(reservoir) x P(source) x P(seal)		<b>6%</b>	<b>15%</b>
Trap geometry and size		<b>Probability of Oil Discovery</b>		<b>0.90</b>	<b>0.90</b>
Up-dip seal		<b>Probability of Gas Discovery</b>		<b>0.10</b>	<b>0.10</b>
Risk of gas / condensate					
<b>CORPORATE EXPLORATION COMMITTEE REVIEW</b>					
<b>Approval(Y/N)</b>	<b>Name</b>	<b>Signature</b>	<b>Date</b>		
	Chris Bulley				
	Malcolm Pattinson				
<b>Discussion</b>					
1.0 Proven, 0.9 Well Defined, 0.7 Defined, 0.5 Poorly Defined, 0.3 Unknown					

## Recommendations

- Plan and optimise proposed well design to limit geological and drilling risks whilst maximising commercial benefit/tax shelter from Ninian appraisal of upswept oil: e.g. nominating footwall degradation complex as initial well objective.
- Evaluate alternative commercial scenarios including, but not limited to: farm-out, asset swap, joint well or bottom hole contributions by 3/3 or 3/8b groups to a well located in the neighbouring block.
- Open discussions with Kerr McGee on best means of advancing Ronan and Jude South with a single well.
- Strong recommendation to resolve all commercial and partnership issues prior to drilling to ensure full alignment of participants.

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