Latvia's First Offshore Round – its Potential and Perspectives

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ABSTRACT

The first Latvian Offshore Round, opened in April 2001 and closing by January 2002, renders a variety of opportunities related to oil exploration and production from Early Paleozoic reservoirs.

Principal reservoirs of the general area are Middle Cambrian sandstones, they are expected to hold most of the oil potential in th offered licenses. Additional opportunities were identified by means of geological modelling, in the Ordovician and Silurian carbonate succession. These opportunities are related to indicated inversion structures, i.e. to their fracturing, and to seismically identified reefal build-ups.

The terms of the Latvian Round are favourable, they obviously honour the magnitude of the expected potential. Likewise, market conditions were found to be favourable.

1 INTRODUCTION

The Latvian Minister of Economy announced the country's first offshore licensing round [1] on April 19th 2001. The round offer comprises two parts: one covers the tender of E&P licence rights, involving 3 licences in the SW of Latvia's offshore and comprising a total of 2,675 sqkm, with a closing date on January 25th 2002, whilst the other, with its closing date on October 31st 2001, offers pre-investigation rights, covering major parts of the Latvian shelf (Fig. 1). The differentiation into two parts reflects the differing expectations of Latvian authorities with respect to work programmes: The first is deemed to be covered adequately by seismic and drilling data, allowing for a reasonable work programme offer, the second is expected to see further exploratory investigations before entering into the committment phase.

From the early nineties onwards data compilations, interpretations and publications [2, 3, 4, 5] were made available to the industry. In addition, upon round opening, selected data, particularly well data, were made available via website / internet. With respect to E&P activities, Latvia and its neighbours during that time also have substantially contributed to attract interest in the general area, i.e. in exploring for oil from Early Paleozoic reservoirs at shallow to moderate depths. Particularly the block allocations to AMOCO / OPAB on both sides of the Swedish / Latvian offshore border, the round openings in Poland's and Lithuania's onshore areas, the production start up in the Polish offshore B 3 structure, the negotiations for settling border disputes in the offshore, and the commissioning of studies to assess oil and gas potentials, led to an increased interest in this oil province.

Upon the announcement of the round opening, the authors had revisited the Latvian areas on offer for their merits [6, 7], with focus on hydrocarbon potential, terms, costs and marketing. The underlying geological evaluations resulted in the modification of concepts, which are the (1) carbonate depositional pattern, (2) structural style and (3) migration possibilities. As a consequence, this summary is aimed at presenting both the geological concept modifications and their bearing on the E&P potential.

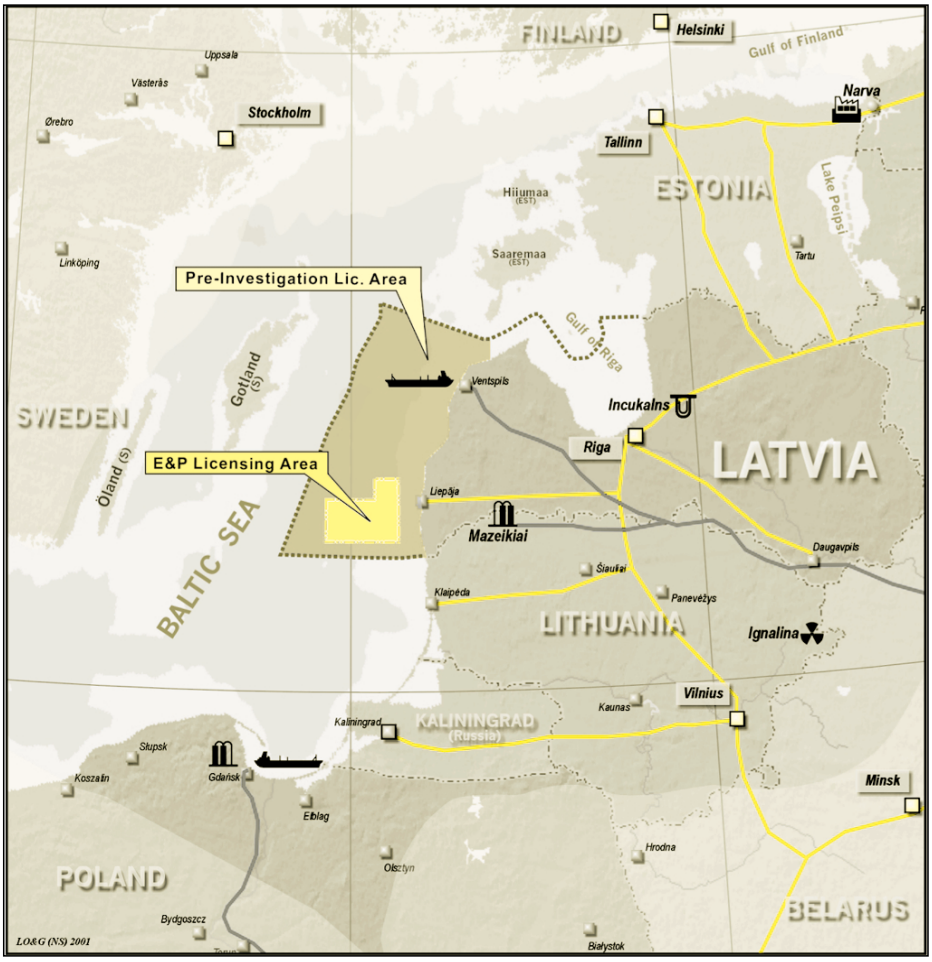

Fig. 1 Baltic Sea region orientation map, with basin outline, Latvian round areas and infrastructure

2 OIL GEOLOGY

2.1 Regional Setting

The Latvian offshore area is part of the Baltic Syneclise (Figs. 1, 2, 3). This mainly Early Paleozoic basin formed on the western margin of the East European Platform. Evolution analyses [8, 9] suggest

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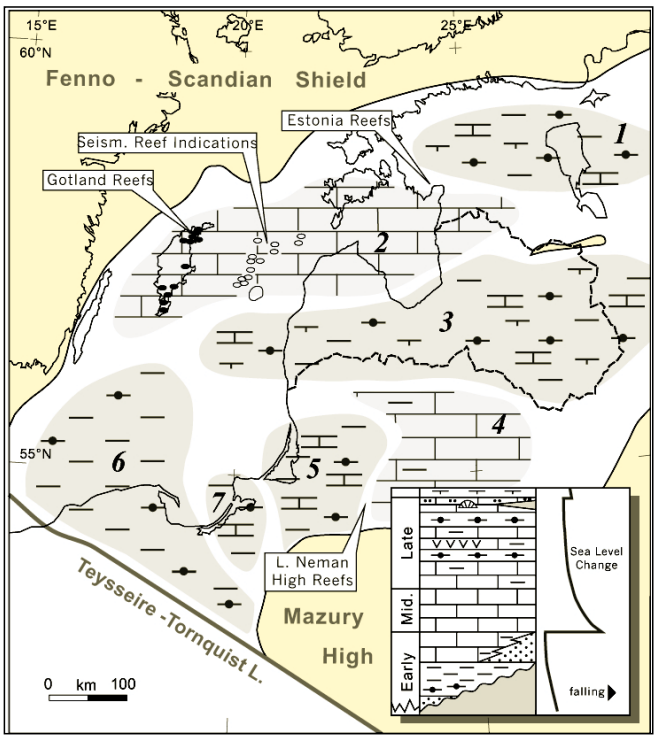

Fig. 2 Ordovician succession: facies belts, stratigraphy and sea level changes. For explanations see text

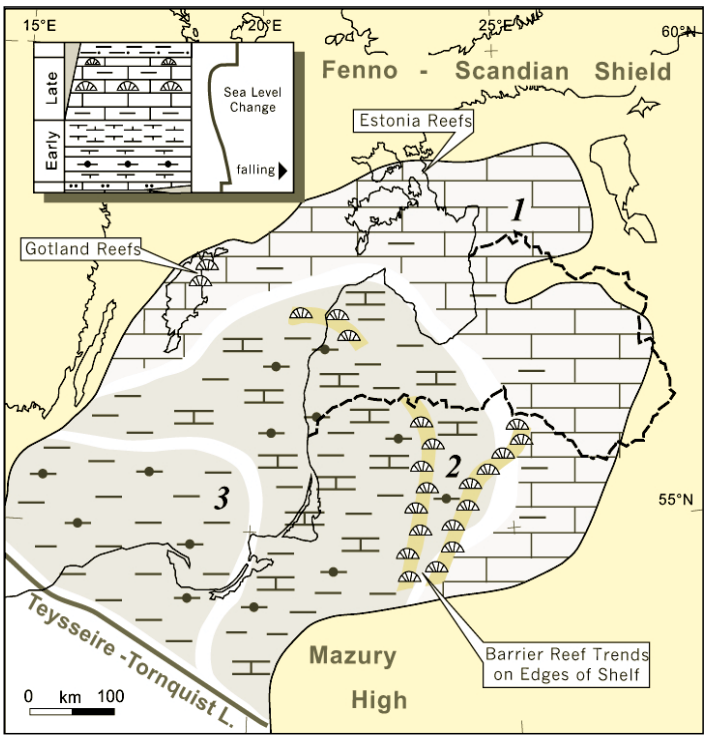

Fig. 3 Silurian succession: facies belts, stratigraphy and sea level changes. For explanations see text

that the Early Paleozoic setting mainly reflects the interaction of the Laurentia and Baltica Plates (the latter, simplified, turning into the East European Platform at a later stage). From Late Precambrian / Mid-Cambrian these plates separated, and the Iapetus Ocean opened. Successively, convergent margins developed, and reinforced convergence – accompanied by orogenic events (Taconian Orogeny) – obviously led to subduction during the Ordovician. At Late Ordovician through Early Silurian Baltica locally was emergent. Eventually, the Late Caledonian continent to continent collision, at Late Silurian through Early Devonian, resulted in the suturing of Laurentia and Baltica.

Evidently, the Late Caledonian Orogeny has most affected the structural setting of the general area – the outstanding feature being the Liepaja-Saldus Ridge which crosscuts Latvia's on- and offshore territories in a SW–NE direction. Locally, this ridge shows heavy faulting.

A somewhat camouflaged, yet significant element in the tectonic setting appears to be the occurrence of inversion, correlated with the orogenic event. Examples of upthrusting exist on the N–S running Leba High feature of Poland, and on the Liepaja-Saldus Ridge, both in the offshore (see Fig. 4) and in the onshore, where on the Incukalns gas storage structure drilling proved the repetition of section owing to upthrusting.

Generally, the basin is referred to as an intracratonic basin [9, 10]. Ulmishek [10], having evaluated in detail the various criteria met – or not met, suggests that the Baltic Basin had been produced as „a hybrid between an intracratonic basin and a passive margin". This comes closest to our modelling [7] of the basin, being mainly derived from the platformal character of carbonate deposition at both Ordovician and Silurian times. Analysing the tectono-sedimentary setting of the two periods suggests that major parts of the Ordovician were formed under conditions of a *differentiated carbonate shelf*, whilst most of the Silurian succession was formed under *ramp conditions*. Both settings are separated by a gap. Comparable settings, however at larger scale, were described by Murris [11] from the Arabian Platform.

The platform covers major parts of the Baltic Sea, including the Swedish islands of Gotland and Oland, and as far as onshore areas are concerned, Estonia, Latvia and Lithuania, together with the Kaliningrad Oblast and northernmost Poland. Transition to the southwesterly deeper water regimes takes place along the *Teysseire-Tornquist Lineament*.

To illustrate the model, the essential data have been compiled on Figs. 2 and 3, employing various sources [6, 10, 12, 13, 14]. Fig. 2 shows the generalized and schematic Ordovician facies distribution, together with the generalized Ordovician stratigraphy of Latvia, correlated with the sea level changes, as adapted from Leighton & Kolata [9]. The outlined facies entities (1 to 7) mainly correspond with the palaeogeographic features referred to by Ulmishek in his compilation [10], which are the North Estonian Depression (1), the South Estonian Uplift (2), the Jelgava Depression (3) and the Lower Neman Uplift (5). The North Polish Uplift (6) and the Natanga Depression (7) derive from Geodekyan [12], identified through thickness mapping, whilst the Mid Lithuanian Unit (4) has been adopted from Lithuanian data [13].

Altogether, the data suggest the setting of a differentiated shelf, having existed at sea level high stand, with source shale sedimentation predominantly in the low areas, and with reefal build-ups correlated particularly with high areas. As to the occurrence of source rocks, the Estonian kukersite are the most outstanding ones, whilst as to carbonate build-ups, the productive Gotland reefal features are the spectacular ones, together with those described by Ulmishek [10] from the Lower Neman Uplift and possibly those build-up clusters identified on seismic [15] in the Latvian offshore, east of Gotland (see Fig. 2). The setting typically also hosts oolitic-bioclastic carbonates, at Ashgill level.

Fig. 3 depicts the Silurian facies belts, together with Latvia's Silurian stratigraphy, correlated with the curve of global sea level changes. Sources of information are as for the Ordovician. The facies belts obviously correlate with the basin's palaeo-highs and lows: (1) the Latvian – Estonian Slope, the Lithuanian Depression (2) and the South Baltic Depression (3). The latter two names are taken from the referred to thickness mapping [10], whilst we would emphasize that Ulmishek's "Latvian Uplift" feature which cuts into (2) is not considered a Silurian palaeo-feature (see also [12])and has no support in facies mapping.

Altogether, the data suggest a setting which contrasts with that of the Ordovician. The map suggests the conditions of a ramp, with facies belts running almost parallel to the strike of the slope, the latter being deduced from thickness mapping [10]. The stratigraphic succession suggests falling sea

level conditions for the major part of the section. Source shale sedimentation predominates in the low areas, and reefal build-ups developed obviously on both sides of the transition from the outer to the middle facies belt. As to the occurrence of source shales, the Llandovery graptolitic shales, predominating in (2) and (3), are the most conspicuous ones, whilst as to carbonate build-ups, the partly oil productive "reef zones" [10] of central Lithuania are the most obvious ones, together with the bioherms and biostromes that crop out on the island of Gotland [16]. Typically, otherwise the carbonates have poor reservoir properties.

2.2 Oil Habitat

2.2.1 Sealed Reservoirs

Main reservoirs of the Baltic Sea oil province are the Middle Cambrian quartzitic sandstones of the Deimena Fm. Reservoir properties show a wide range, with porosities measured from appr. 2% to some 25%, and permeabilities ranging from few mD to appr. 1 D. Porosity deterioriation increases with depth of burial [17, 18], which means that at the moderate burial depths reached in Latvian areas, porosities are only moderately affected by diagenetic effects. The oil flow potential is moderate. The range is from a few bbl / d to up to some 3,500 bbl / d, whereby the higher flow rates are partly achieved from horizontally drilled sections and / or upon underbalanced drilling. In Latvia, the Kuldiga field had temporarily produced from this level.

As for Ordovician carbonates, those of Ashgillian age are probably the most promising ones in terms of reservoir characteristics. On the island of Gotland, Ashgillian reefal build-ups are oil productive. The oil flow potentials are low. Other Ashgill carbonate reservoirs are the oolitic – bioclastic limestones which were found oil-stained in several Latvian onshore wells, with porosities up to 20%. Remarkably, the Latvian offshore E 6 well yielded an influx of appr. 20 bbl / d on test from a reservoir with 17% porosity and insignificant permeabilities, and also Lithuania's Kybartai field, on the edge of the Lower Neman Uplift (see Section 2.1), exemplifies oil production from Late Ordovician carbonates, despite poor reservoir properties.

Within the Silurian succession, evidence for reservoirs is scarce. Only the Lithuanian Kudirka area with its three pools yields evidence for oil productive reservoirs, related to the a.m. Ludlow reefal build-ups. Maximum porosities are 15%, maximum permeabilities are 122 mD.

2.2.2 Mature Source Rocks

Within the preserved section of the basin, three outstanding source rock levels are identified: the Late Cambrian and Tremadocian alum shales, the Ordovician (Caradoc) shales, and the Silurian (Llandovery) graptolitic shales [4, 17, 19]. Other source rocks exist, yet are less significant.

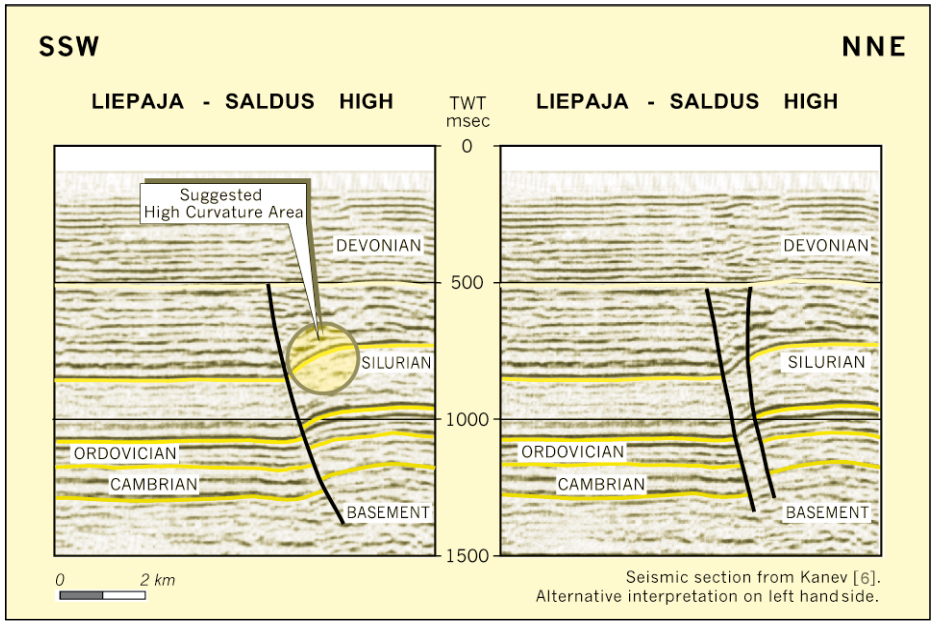

Fig. 4 Latvian offshore seismic line across suggested inversion structure, with potential fracture zone ("high curvature area")

The alum shales' lateral equivalents attained oil maturity in the North Polish part of the basin and in basinal areas adjoining to the east. Upon intra-Early Paleozoic uplifting and erosion the Late Cambrian alum shales are absent in parts of the basin. This also holds true for Latvia.

The Ordovician source rocks are comprised in the carbonate section as shale layers. In the southern areas they have reached oil maturity, whilst in Latvian areas (and further north) they are immature to early mature, except for potentially local kitchen areas [3] which are suggested to yield appropriate maturity, for subsidence reasons.

The Silurian source rocks likewise are showing maturity in the southern areas and immaturity to marginal maturity in Latvian territories (and further north). Again, exceptions for local kitchens may exist.

Analyses of the source rocks [4, 17, 19] seem to indicate that TOCs do not differ much, i.e. are mainly in the order of 10 to 20% and that facies are varying little, i.e. are typically kerogen type II. The yields upon pyrolysis exhibit larger ranges, from some 20 kg to some 70 kg HC per ton of rock. However, the variation is suggested to likely reflect different maturity stages [6].

A particular critical factor, controlling the entrapment of oil, is in this basin the time of oil generation and migration. Consensus amongst those who modelled the maturation history [4, 17, 19] is that the oil window was reached at appr. end Silurian times and that the main phase of generation (and / or subsequent expulsion / migration) had started by Early, Mid or Late Devonian.

2.2.3 Petroleum System and Plays

Oil to source correlations [19] indicate no unequivocal allocation of the reservoired oils to specific source rocks. The authors, who investigated Lithuanian samples, suggest that the oils trapped derive from several source rocks. Consequently, and also for the reason that no difference in timing as to oil generation from the different source rocks has been found, it appears reasonable to base the basin modelling on an Early Paleozoic Petroleum System, with the understanding that Late Cambrian and Tremadoc, Late Ordovician and Early Silurian source rocks are the potential and likely contributors.

Reservoirs which are sealed and which are in the reach of mature source rocks, are the ones to render the productive plays. These are the Mid Cambrian Sandstone Play, the Late Ordovician Carbonate Play, the Late Ordovician Reef Play, and the Late Silurian Reef Play. Vital elements of the plays appear to be long range migration [3, 4, 17] and, for the Mid Cambrian Play, the presence of faults that juxtapose the stratigraphically higher source rocks.

2.2.4 Fields and Reserves

The majority of the fields found since 1963 is oil-bearing at Middle Cambrian level. This holds true for the North Poland onshore fields [17], the Polish offshore fields , the Kaliningrad Oblast fields and the Lithuanian fields [19]. Recoverable reserves range from some 0.2 MM bbl oil to about 63 MM bbl oil of the Kaliningrad D 6 offshore field [1]. Obviously, however, the bulk of the more than 30 fields contain small reserves, the referred to D 6 field is outstanding in size.

Ordovician fields in total produced some 0.7 MM bbl oil on Gotland island [20], which represents the EUR from at least 12 pools. The reserves of the referred to Lithuanian Kybartai field are estimated at appr. 0.6 MM bbl oil [19].

The only Silurian field, located in Lithuania (see Section 2.2.1) which shows up on

production statistics, is estimated to contain appr. 2.0 MM bbl oil [19].

2.2.5 Results of Play Revisiting

The apparent limited potential of the area – as compared to its major neighbouring oil provinces, the North Sea and the Russian Basins – mainly reflects (1) reservoir insufficiencies at Orvovician and Silurian levels, (2) the lack of a substantial number of large structures, and (3) the delicate relation between structuring and migration. In our model, we suggest that

– at Ordovician and Silurian times reservoir-prone facies developed along palaeo-highs and slopes and / or shelf breaks, with reef clusters, reef zones, or bioclastic-ooidal carbonates,
– from end Silurian times onwards early mature source rocks commenced charging the reefal stratigraphic traps (whilst possibly larger amounts of HCs migrated updip without being trapped), upon focussed migration,
– at the Late Caledonian Orogeny times structures, faults and fractures formed, involving Cambrian sandstones and Ordovician and Silurian carbonates. Particularly inverted, upthrusted sections, owing to potentially intense fracturing along pronounced curvature areas of the strata, may have undergone poro-perm enhancement,
– at post-Middle to Late Devonian times traps of the Early Paleozoic section were available for oil entrapment, as migration became re-oriented.

It is obvious that in terms of oil entrapment the most favourable areas are those which were palaeo-highs at an early stage and which remained high areas.

3 ROUND PERSPECTIVES

3.1 The Potentials

Potential estimates as related to prospects offered through the round are, for good reasons, not released. In the following it is solely attempted to check the sizes of model fields against reality of the eastern Baltic Sea area.

3.2 E&P Licensing Areas

The main reservoir is expected to be the Middle Cambrian sandstone, the reservoir capacity of which had been tested in the E 6 well, located in the licence on offer. Structure mapping as published [6] indicates the presence of structural closures ranging between some 10 and 35 sqkm (2,500 and 8,500 acres). Upon application of net pays known from Middle Cambrian reservoirs it is estimated that recoverable reserves relate to some 16.1 standard cum per cukm of gross rock volume (Sm3 / km3 GRV) – this does not infer the need for fracturing since the reservoir depth is expected above the critical depths for diagenetically induced reservoir deterioriation. The model field size results in an order of magnitude of 32 MM bbl oil. This is approximately the size of the producing B 3 field in the Polish offshore. The D 6 field size (see Section 2.2.4) would be reached by adding the potential upside, i.e. another 32 MM bbl oil.

Modelling a carbonate case, based on the model of a fractured, primarily low porosity reservoir, i.e. by using 6.4 Sm^3 / km^3 GRV (see above), smaller reserves are arrived at. This is also due to the fact that the productive area, mainly controlled by the curvature of the reservoir (see Section 2.3), is smaller.

It is noted that the estimates for the AMOCO / OPAB structure straddling the Swedish / Latvian offshore border (see Section 1) are considerably higher, according to one source [21] more than ten times higher than the model field of above.

Table 1 **Key licensing terms of Latvia's 1st offshore round**

	E&P Licensing	Pre-Investigation Licensing
Blocks on Offer	7 (forming 3 Licenses) – covering 2,675 sqkm	66 - covering 17,850 sqkm
Contract Type	E&P – Royalty/Tax	Reconnaissance (on "Areas for Prospecting")
Contract Partner	Latvian State through LDA, carried @ 10% or higher	Not applicable
Contract Duration	5 years Exploration, 30 years total	2 years contractual 5 years upon Extension
Work / Expenditure Obligation	To be offered / specified by Applicant	To be offered / specified by Applicant
Fees / Boni	Application Fee 2,400 Lats., Signature Bonus 75,000 Lats.	Application Fee 800 Lats., Signature Bonus 2,000 Lats.
Royalties	Sliding Scale, ranging from 2% @ 10,000 BOPD to 12 % @ above 80,000 BOPD	Not applicable
Taxes	25 % Corporate Tax	Not specified
Other Items	• No partial Relinquishment Obligation • No Gas Clause • Utilisation of local Services asked for • Locals' Training asked for • Environment Protection imperative	Environment Protection imperative

3.3 Pre-Investigation Licensing Areas

The Pre-Investigation Licensing areas fundamentally host the same prospect types as the E&P Licensing areas, particularly in the southernmost offshore parts.

In addition, seismically indicated Ordovician reefal build-ups east of Gotland are suggested to offer the opportunity of finding oil. Based on parameters from the Silurian Kudirka reef (see Sections 2.2.1 & 2.2.4), potential estimates indicate that either the cluster of reefal build-ups, to be treated as one entity, or the largest build-up, south of the cluster, having been identified on several seismic lines [15], would be drilling targets, subject to further seismic [15].

3.4 The Round Terms

Latvian round terms are, without doubt, favourable. The principal term elements are highlighted on Table 1. They show the rationale behind the terms setting: to attract licensees who would commit to work programmes reflecting their assessment of the licenses' potentials. This holds true for the E&P Licensing part, and even more so for the Pre-Investigation Licensing part.

Already from pre-development studies of the most prominent and most attractive discoveries made in this part of the Baltic Sea, i.e. from the B 3 field of the Polish offshore, and from the D 6 structure of the Kaliningrad Oblast offshore, it is known that the issue of economic viability is of paramount significance. Critical factors in this are particularly well rates and the size of recoverable reserves. Obviously, the Latvian round terms honour both these experiences and the respective predictions of Latvian offshore potentials.

3.5 Marketing Conditions

In Latvia, conditions to achieve competitive prices at the wellhead – an issue identified by van Meurs [22] as being essential for the success of any E&P venture – are obviously favourable. Reasons for this assessment are: (1) no market, volume or price regulations for oil (or gas) are in force, (2) licencees may fully and according to their own conditions dispose of their share in production, and decide on exporting or marketing locally, (3) profit repatriation is guaranteed, and no currency exchange restrictions exist, (4) local marketing is attractive as local demand for energy is forecasted to grow (despite the fact that energy consumption did not grow in Latvia from 1996 to 1999, i.e. went down from 6,759 to about 6,400 ktce), (5) the infrastructure of the region (see Fig. 1), comprising Latvia's Ventspils oil terminal and Lithuania's Mazheikiai refinery, facilitates market reach, and (6) the expected oil quality from the offshore (about 38° API) would be satisfactory.

3.6 Costs in E&P

Costs in terms of finding costs or, finding, development and production costs, are not readily available. This is mainly because the previous activities of the PETROBALTIC venture had been carried out under different conditions and different economic guidelines.

Whilst the estimate of development and production costs, at this point in time, will contain uncertainties, the assessment of finding costs may be less problematic. The progress achieved in the regional understanding of the plays, the availability of seismic data, including reprocessed data sets, and the knowledge of the reservoir parameters from the neighbouring areas are expected to render a fairly high success ratio and to contribute to minimizing costs, i.e. unit costs (in US$ per barrel).

4 CONCLUSIONS

The Latvian first offshore round evidently renders opportunities as far as exploration for and production of oil from Early Paleozoic reservoirs is concerned. Through its liberal attitude concerning data release, Latvia allowed for early evaluations of the offer – including the review and revisiting of exploratory concepts.

From the assessment of both technical and non-technical E&P factors it is concluded that

– *potentials*, together with reservoir properties and well rates, are the most critical issue. Successful development and production in the Polish B3 offshore field, however, are suggested to render the case history,
– the round *terms*, being favourable according to international standards, adequately reflect the potential of the area,
– favourable *marketing conditions*, both circumstancially and through actively taking measures, sustain the round offer, and
– *costs*, in terms of unit costs, are expected, as far as finding costs is concerned, to be potentially low, reflecting past experience and activities.

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