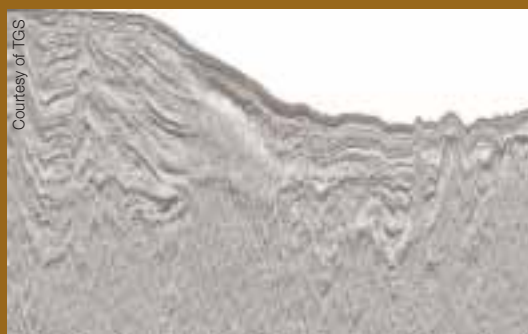


Multi-client seismic spurs interest

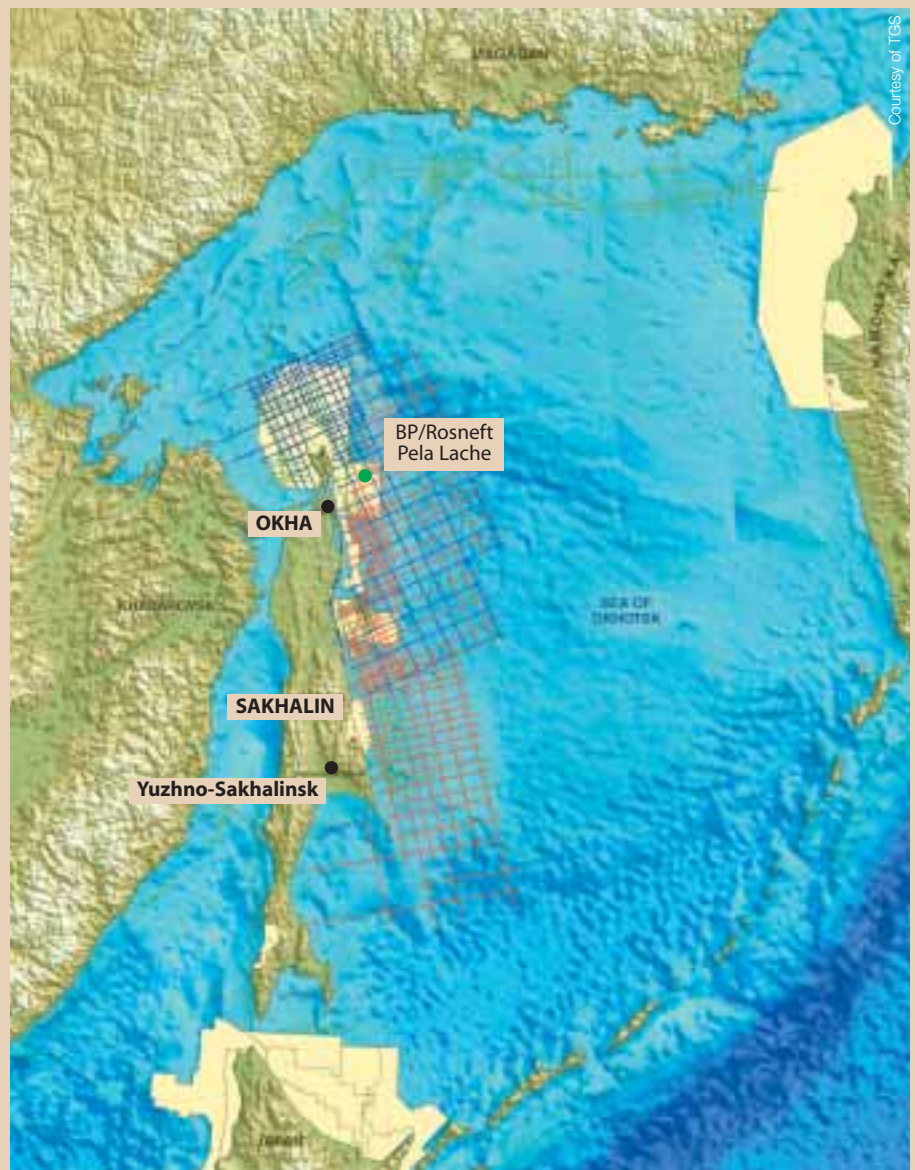
The Northeast Sakhalin Shelf, with several giant fields already discovered and put on production, is recognised as a world-class petroleum province. New seismic acquired in the rest of the Sea of Okhotsk indicate that there is more to be found.



Courtesy of TGS



Dalmoreftegeofizika has acquired a huge seismic data base covering almost the entire Sea of Okhotsk. New, modern data is now made available through a cooperation with TGS Nopec.



The Sea of Okhotsk is named after Okhotsk, the first Russian settlement in the Far East. It is the northwest arm of the Pacific Ocean covering an area of 1,528,000 sq km, lying between the Kamchatka Peninsula on the east, the Kuril Islands on the southeast, the island of Hokkaido belonging to Japan to the far south, the island of Sakhalin along the west, and a long stretch of eastern Siberian coastline along the west and north. Most of the Sea of Okhotsk, except for the area around the Kuril Islands, is frozen during from November to June and has frequent heavy fogs. In the summer, the icebergs melt and the sea becomes navigable again. The sea is generally less than 1,500m deep; its deepest point, near the Kuriles, is 3,363 m. Fishing and crabbing are carried on off W Kamchatka peninsula. The DMNG/TGS Seismic acquired in 1998, 2004 and 2005 is shown in green, blue and red colours. Note also the location of Okha where oil seeps were found 125 years ago.

On the shelf of the Sea of Okhotsk, mainly off the coast of Sakhalin, the world's largest oil companies are actively exploring for and exploiting oil and gas resources together with several Russian companies. The region is highly productive and exceptionally important for fisheries.

Halfdan Carstens

Oil and gas have been produced in the North Sakhalin Basin since 1927 from a large number of small onshore fields. Offshore, giant discoveries have been made in the same basin, and this has spurred the interest for exploring in other sedimentary basins offshore Sakhalin. This interest is now reaching further out, to the rest of the Sea of Okhotsk as more seismic data is acquired and interpreted.

The Sea of Okhotsk thus represents another example where non-exclusive seismic data is a key tool to explore in a frontier area, the principle being that of dispersing cost and risk amongst several oil companies.

"The challenge in the case of Sea of Okhotsk lies with central and local Russian authorities. It is important that the terms permit and stimulate non-exclusive data acquisition: All parties will benefit. Russian seismic contractors will play an important role, and Russian authorities will experience higher interest and increased competition for exploration acreage," says Kjell Trommestad, Vice President and General Director Europe of TGS NOPEC.

First onshore – then offshore

Exploration on the Sakhalin Island dates back more than 100 years, to 1879, when a local hunter found oil lakes and numerous oil seeps near Okha on the northeast coast.



Seismic line through the Lunskeye gas-condensate field offshore Sakhalin shows the gas cloud above the proven field and channel deposits immediately to the east, not imaged on older vintage seismic in the area.

This encouraged the first exploration drilling in the 1890's, but it was not until 1923 that the Sakhalin Trust struck oil and discovered the Okha field (compare map) that began producing four years later.

During the next 40 years eight new fields were discovered, and by the end of the 1950's all of the large anticlines mapped onshore had been tested to depths of 2.5 km. Deeper targets were thereafter drilled based on seismic data. By 1971, a total number of 35 onshore oil and gas fields

had been discovered.

Offshore exploration began in earnest in 1968 with the drilling of a deviated onshore well into the offshore region. Modern activity was initiated during the first half of the 1970's, first through a co-operation between Soviet Union and Japanese companies, followed by a phase of activity by Russian companies alone, and eventually the entrance of international exploration companies came in the late 1980's and early 1990's.

Marine drilling did not begin until 1977. "From 1977 to 1989, 22 wells were drilled and a number of significant oil and gas discoveries were made offshore Sakhalin, including Odoptu (1977), Chaivo (1979), Lunskeye (1984), Piltun-Astokhskeye (1986) and Arkutun-Dagi (1989)," says Deputy Director Vladimir Kudelkin of Dal'morneftegeofizika Trust, which is headquartered in Yushno Sakhalin on the Sakhalin Island.

During the next few years, in the early 1990's, an aggressive exploration campaign followed both inside and outside the main fairway. A number of structures were drilled on the northeastern shelf, the southwestern shelf and the western shelf. The Aniva Bay and the Terpeniya Bay were also tested. "The five wells drilled were all dry. The main reason for this was that there were no reservoirs," says Kudelkin.

World-class province

"Exploration in the Sea of Okhotsk has to a large extent been limited to the areas





Vladimir Kudelkin is Deputy Director of Dalmorneftegeofizika Trust (DMNG) and has been involved in exploration in the Sea of Okhotsk for more than 20 years.

offshore Sakhalin. Offshore production started in 1999 and is taking place from the North Sakhalin Basin where prospectivity is related to a combination of excellent reservoir rocks, effective seals and simple structures," says Kudelkin.

"This has established offshore Sakhalin as a world-class hydrocarbon province. Accumulated reserves are in excess of 5.5 billion barrels of oil and 35 trillion ft³ (6.3 billion barrels of o.e.) of gas. Dalmorneftegeofizika has estimated the oil and gas resources in place to be in excess of 90 billion barrels of oil equivalents. In comparison, total accumulated production on the UK continental shelf is in the order of 30 billion barrels of oil equivalents."

As offshore exploration has been very limited we expect that many major discoveries will be made in the future," Kudelkin adds.

Current investors in the area include major oil companies like BP, ChevronTexaco, ExxonMobil, Rosneft, Shell and TNK-BP.

Stepping out

"Despite the established prospectivity of the region, offshore exploration activity has so far been restricted to a narrow corridor east of the Sakhalin Island, where all of

the above mentioned discoveries are located. The Pela Lache well drilled by Rosneft/BP in Sakhalin V in 2004 represents the first step outside the established fairway," says Trommestad.

In 1998, BP formed an Alliance with Rosneft to explore in Sakhalin via an exclusive bidding agreement (BP 49%, Rosneft 51%). In June 2002, Rosneft obtained the first exploration licence on behalf of the Alliance for the rights to explore Kaigansky-Vasukansky blocks in the south of the Sakhalin V area, which had no previous exploration history.

The first well in the block "encountered significant volumes of oil and gas in a number of high quality sandstone reservoirs," according to BP. It was drilled "farther north, farther offshore (49 kilometres), and in deeper water (114 metres) than any previous well offshore Sakhalin. This well marks the first drilling activity in the modern stage of Sakhalin oil and gas exploration."

"The results of Pela Lache -1 represent a positive first step towards opening a new area for exploration and subsequent development offshore northern Sakhalin," BP said. "This is a first confirmation of a prolific trend extending to the east and could lead

to opening of new areas for exploration and subsequent development offshore north Sakhalin," says Trommestad who has seen the modern seismic data in the Sea of Okhotsk acquired by TGS NOPEC in cooperation with DMNG."

Excellent petroleum system

The Sea of Okhotsk is a large marginal sea located at a triple junction with the Eurasian Plate to the north, The Pacific Plate to the south and the North American Plate to the east. The larger part of the Sea of Okhotsk is occupied by the Okhotsk sub-plate, which suffered several rifting phases during Tertiary times: in Eocene-Oligocene, Middle Miocene and Pliocene.

The Kamchatka and Sakhalin orogenic systems were formed along collision boundaries of the Okhotsk sub-plate due to transpression regime.

"More than twenty discrete petroleum basins are present in the Sea of Okhotsk, and the depocentres have several similarities. The region may therefore considered

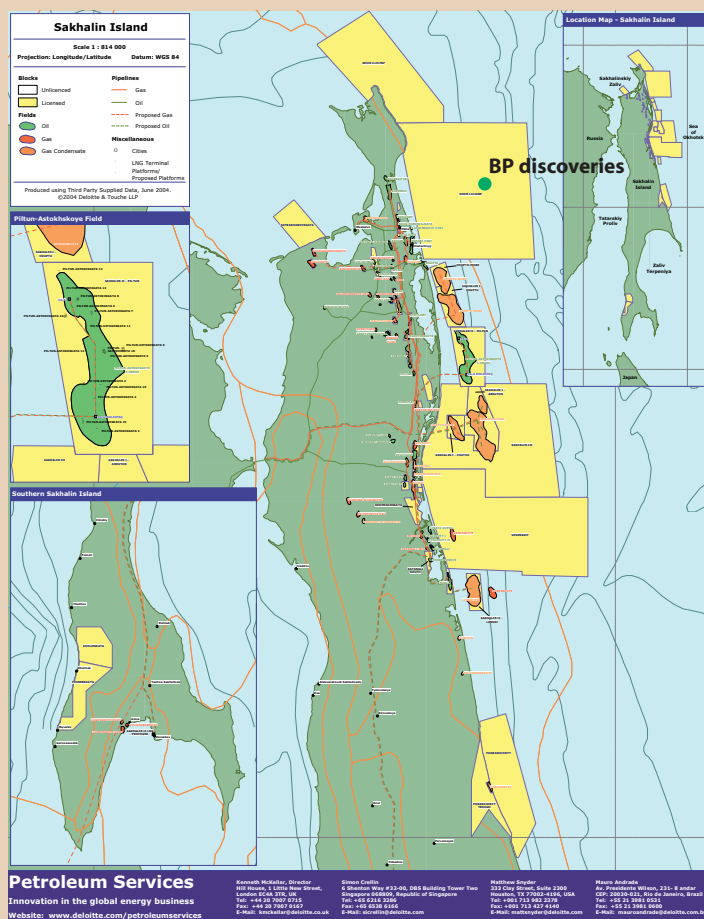
DMNG and TGS NOPEC

Dalmorneftegeofizika (DMNG), a Russian seismic company based in Yuzhno-Sakhalinsk, and TGS-NOPEC Geophysical Company (TGS), a Norwegian/American company specialising in multi-client seismic have jointly carried out a number of multi-client seismic projects throughout the world for more than 10 years. During the last 6-7 years, the multi-client concept has also been successfully implemented in the Sea of Okhotsk in the Far East Russia. This activity has played a significant role in the exploration for oil and gas in this region.



Photo: Erling Frantzen

DMNG's premises in Yuzhno Sakhalin.



License areas offshore Sakhalin as of June 1, 2005. The recent discovery made by BP lies in Sakhalin V and represents a new play which give further incentives to extend exploration away from Sakhalin.

The Sakhalin-1 project

The Sakhalin-1 project includes three offshore fields: Chayvo, Odoptu, and Arkutun Dagi. Exxon Neftegas Limited is the operator for the multinational Sakhalin-1 Consortium. Co-venturers include the Japanese consortium SODECO (30 percent); affiliates of Rosneft, the Russian state-owned oil company, RN-Astra (8.5 percent) and Sakhalinmorneftegas-Shelf (11.5 percent); and the Indian state-owned oil company ONGC Videsh Ltd. (20 percent).

Sakhalin-1 potential recoverable resources are 2.3 billion barrels of oil and 17.1 trillion cubic feet of gas (485 billion m³ of gas). Sakhalin-1 will be one of the largest single foreign direct investments in Russia.

The Project will be executed in phases. The initial phase develops the Chayvo field with production start-up targeted for the fall of 2005. A dedicated oil pipeline and terminal facility at DeKastri on the Russian mainland will export crude oil to world markets beginning in 2006. The initial gas production will be sold in the Russian Far East domestic market. Export of the remaining gas reserves via pipeline will commence when a contract with a regional customer is secured. The Odoptu and Arkutun Dagi fields will be developed as subsequent phases.

The Chayvo field will be developed from both offshore and onshore facilities. The Chayvo Yastreb land rig is designed to drill extended reach wells to offshore targets from land based locations. In June 2003, a shore-based extended reach programme (ERD) to install wells under the seabed at distances exceeding 11 km to tap the northwestern flank of the main Chayvo oil zone was initiated. Six ERD wells have been drilled to-date from Yastreb.

Oil and gas will also be produced from an offshore platform. The 20-well concrete structure will serve as the offshore drilling and living quarters and will be used to develop the southwestern flank of the main Chayvo zone. Installation of Orlan at Chayvo is currently under way. The Orlan drilling rig will be operated on the platform year-round.

The Chayvo Onshore Processing Facility will produce at the rate of approximately 250,000 barrels of oil per day and 800 million cubic feet per day.

A 24-inch pipeline will be built from the Chayvo OPF to the DeKastri export terminal on the Russian mainland. The pipeline construction started in 2004 and is scheduled to be completed at the end of 2005.

in terms of a relatively simple petroleum system," says Vladimir Kudelkin.

Kudelkin explains that there are two principal source rocks, both of which are Tertiary in age. It is the Palaeogene lacustrine and shallow marine shelf with kerogen type II and III that give both oil and gas and the Miocene marine shales with kerogen type II that give predominantly oil. The quantity of organic matter in the source rocks ranges from 0.6 to 4.2% and the geothermal gradient varies between 2.4 to 4.4 °C/100 metres. "The Golden Zone" (GEO ExPro no. 2, 2004), which supposedly contains 90% of the hydrocarbons in a sedimentary basin, should therefore be found approximately between 1500 and 5000 metres below the surface.

"The best reservoir rocks in the region are stacked deltaic sandstones deposited by the Neogene palaeo-Amur system since Early-Middle Miocene. Seismic data tells us that the delta extended much further north and east than Sakhalin in Eocene-Early Oligocene times. Individual sandstone beds vary in thickness from several tens of metres up to more than 100 metres. The sandstones have excellent reservoir characteristics with multidarcy permeabilities and porosities greater than 20 percent," says Kudelkin. In the South Sakhalin area fractured Oligocene siliceous mudstones are potential reservoirs.

"In the Magadan and West Kamchatka areas distribution of potential reservoirs is little known but thick Palaeogene fluvial sandstones are probably the best potential reservoirs."

A variety of structural traps are present with Miocene-Pliocene wrench fault movements being most important.

"The small onshore fields occur within strongly faulted anticlines associated with Late Pliocene-Pleistocene inversion, says Kudelkin."

The principal play model in the region is hydrocarbons in reservoirs that are associated with the palaeo Amur delta system, sealed by shales and sourced from the Palaeogene.

Exclusive agreement

"Our current understanding of the regional geological setting in the Sea of Okhotsk is based on evaluations and interpretation of old seismic data with clear



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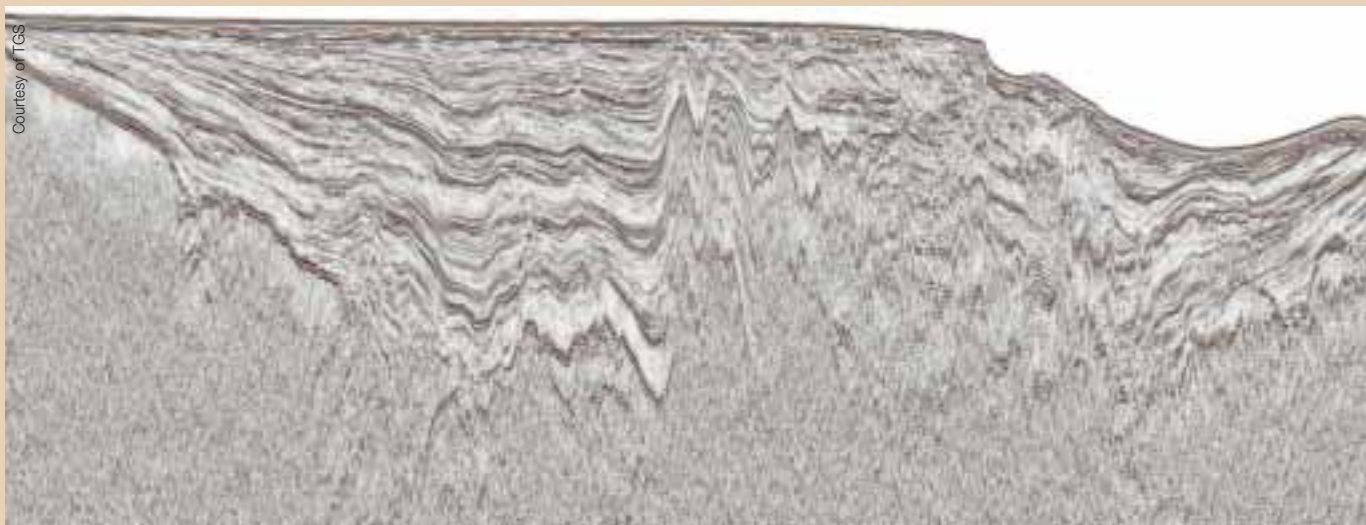
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Seismic line north of Sakhalin Island shows high quality image and good definitions of local Tertiary basins above basement north of Sakhalin Island. The structural high in the middle of the section is the northern prolongation of the island itself. East of the high lies the Derugin basin. No wells have been drilled yet in this area. The line is 250 km long.

limitations with respect to resolution and sequence definitions. Using modern, high quality seismic a new and better understanding of the area can be obtained. This will certainly benefit future exploration," says Trommestad.

With this background TGS NOPEC in 1998 entered into a 5-year exclusive, renewable agreement with DMNG. The purpose was to make plans, acquire, process and market new non-exclusive seismic 2D-surveys in Eastern Russia, limited in the extreme northeast by the Bering Strait and by Sea of Japan in the southwest. The agreement thus encompasses the Bering Sea as well as the Sea of Okhotsk. From now on new modern seismic data would be available to the industry.

The first programme under joint TGS/DMNG operation (9700 km) was designed to confirm some of the major untested structural trends that DMNG had mapped around Sakhalin Island and on the Magadan and Khabarovsk shelves.

A new era for data

Around Sakhalin Island the 1998 data represented a major improvement in resolution and definition of sequences and structural trends in many of the already established petroleum provinces. Pre-Tertiary sequences, specifically in Sakhalin 4 and 5 areas could now be defined, and undrilled inversion structures in Sakhalin 1, 2 and 3 stood out.

This 1998 programme has confirmed that Magadan geological province con-

tains tilted fault-blocks, horsts, anticlinal structures and pinch out leads of world-class sizes. "The presence of these elements combined with a large number of Direct Hydrocarbon Indicators (DHI's) give reason for optimism in parts of Magadan offshore areas," says Trommestad.

On the Khabarovsk shelf the 1998 survey confirmed a heavily faulted structural trend where Tertiary deep grabens are thought to contain mature source rocks. More extensive acquisition is needed in this area in order to establish confidence in leads and prospects.

New and more data

The agreement between TGS and DMNG has been extended with another five years, and during the summer of 2004 a non-exclusive survey totalling 9,650 km (SA04) was acquired. The purpose was to get a denser grid in Sakhalin 4 (northwest of Sakhalin) and Sakhalin 5 (northeast of Sakhalin), but also to test the idea of Tertiary fan deposition into a huge area east of the Sakhalin, the Derugin Basin, in open areas not covered by seismic before.

Based on review of preliminary data (fig. 3) from the SA04 survey, it is clear that the objectives of the survey have been met. "The new data shows the presence of deep sedimentary basins not previously imaged. These basins could represent a different petroleum system than those we know about and have to be investigated further," says Trommestad.

Based on the results from the 2004 sur-

vey, a third survey was acquired this summer. This is partly an infill to the existing seismic grid, but also a test into Sakhalin 6 to the southeast also to date suffering from poor data quality. The geology in Sakhalin 6 is not fully understood, but gravity and magnetic indicate that huge basins could be present.

"Another significant step forward has been made with respect to data quality, and in combination with the extended coverage towards the deep-water areas of the Sea of Okhotsk, this year's survey will most likely image new structural elements and exploration models to be considered in the future seismic programmes. More data should therefore be acquired in the Khabarovsk, Magadan and West-Kamchatka areas," says Kjell Trommestad.

Industry focus

There is an increasing interest for Sea of Okhotsk among the international exploration companies. Several new players are working with the multi-client data as a part of their initial evaluations, with the aim to establish themselves as active investors and partners in the region. However, key factors will be the availability of exploration licenses/acreage and that the processes and terms related to this are predictable.