Petroleum potential and exploration challenges of ex-USSR and East European sedimentary basins

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Almost all sedimentary basin types described by modern plate-tectonics have been recognized within the territory of the Former Soviet Union (FSU) and Eastern Europe, Bois et al. (1982), Demaison and Huizinga (1991), Helwig (1985), Klemme (1980a, 1987), Kingston et al. (1983) (Figs 1 & 2). They can be divided into three main groups according to their origin and general geodynamic setting:

1. Intracontinental and marginal rifts and aulacogens.
2. Orogenic intermontane and foredeep basins.
3. Cratonic basins.

These basins all have a varying hydrocarbon potential and, the exploration challenges are dependent on many geological and geochemical conditions (Perradon 1984; Green 1985; Ulmishek and Harrison 1986; Magara 1991; Ulmishek and Masters 1993).

1 Intracontinental and marginal rifts and aulacogens

This group of basins were formed by intracontinental or continental-margin rifting. The hydrocarbon potential of these basins is strongly influenced by the extent of plate separation, which controls important parameters such as the rate of sedimentation, the intensity of heat flow, sediment thickness and lithology. Examples are the Pripyat and Dnieper-Donets aulacogen system, the

North Kamchatka–Anadyr and Okhotsk–Sakhalin continental marginal rift basins (Fig. 1). This group of basins also includes the almost unexplored offshore marginal rift basins of the Arctic shelf.
There have been no significant discoveries in the last decade in the Dnieper-Donets and Pripyat aulacogen basins. The remaining hydrocarbon reserves are not significant (Figs 3-4). New exploration targets in the Dnieper-Donets Basin are Middle Devonian synrift clastic reservoirs which remain unexplored, due to the great depth of the structures (over 6000 m).

Greater exploration potential exists in the Okhotsk-Sakhalin basin. The main producing reservoirs are Miocene clastics with remaining hydrocarbon reserves of about 3.1 billion bbl of oil and 33.0 Tcf of gas. New exploration targets are Cretaceous and Palaeogene sandstones in the northern Sakhalin depression.

Recently, new discoveries have been made in the North Kamchatka basin in the so-called ‘Kolpakov Depression’. Reservoirs are Neogene sandstones located at a shallow depth of about 1500 m. Exploration in the Anadyr basin on the Chukotka Peninsula (Fig. 1) resulted in the discovery of small oil and gas fields of the same age. Estimated reserves are 0.2 billion bbl of oil and 2.0 Tcf of gas. However, no further exploration activity has taken place due to the modest size of the
discoveries made so far, the distance of these basins from industrial centres, the lack of infrastructure, and the severe climatic conditions.

The passive continental margins of these basins are also attractive exploration targets. In such basins, wide plate separation leads to turbidite deposition at basin margins providing favourable conditions for prolific petroleum accumulations. The modern plate-tectonic modelling show the existence of Palaeozoic passive continental margins along a palaeo-Ural ocean, which are considered as new exploration targets (Khain et al. 1991).

The latest discoveries in the Barents and Kara sea basins, the large gas-condensate and gas fields of Shtokmanovskoe, Ledovoe, Ludlovskoe, Rusanovskoe, Leningradske, indicate the enormous potential of Arctic passive continental margins.

The estimated potential and remaining hydrocarbon reserves in this group of basins are about 30.0 billion bbl of oil and 1400 Tcf of gas. Some 50% of the oil and 85% of the gas reserves are thought likely to be in Mesozoic clastics in the Barents and Kara Sea basins (Figs 3–4). This indicates that the North Arctic passive continental margins and rift systems offer an attractive exploration potential.

In Eastern Europe none of the sedimentary basins belong to the group of basins described above.

2 Orogenic intermontane and foredeep basins

Orogenic intermontane and foredeep basins result from plate collision. Thrusting is an important tectonic feature of this group of basins. The Eastern European platform is entirely framed by such overthrust belts where displacement reach tens of kilometers and in some areas, such as the Scandinavian Caledonides, hundreds of kilometres.

In the FSU examples are the North Caucasus–Mangishlak, South Caspian, Fergana, Lena–Vilyui, Enisey–Khatanga and Carpathian foredeep and in Eastern Europe, the Pannonian, Vienna and Balkan foredeeps, and Carpathian Flysch (Figs 1–2). They are prospective having oil and gas occurrences in both overthrust and subthrust structures. The main producing reservoirs are shallow marine Mesozoic carbonates and Tertiary continental molasse sediments. The deeply buried fractured subthrust structures and mature ‘oil-kitchen’ provides optimum conditions for hydrocarbon generation and expulsion (Price 1994). The hydrocarbons occur most frequently in pinch-out traps of strongly folded structures of the overthrust nappes or in barrier reefs on the margins of the foredeep basins.

The majority of these basins have been extensively explored, except the East Siberian foredeeps, e.g.
Enisey–Khatanga and Lena–Vilyui, which contain gas reserves of some 70 Tcf in Mesozoic clastics (Fig. 6).

The South Caspian Basin (Azerbaijan and West Turkmenia) underlies some of the oldest oil and gas producing provinces in the FSU. The main producing middle Pliocene sandstone reservoirs are approaching depletion onshore, but new exploration structures in the Caspian sea have estimated oil reserves at 10–15 billion bbl (Fig. 5). In onshore Turkmenistan, this basin has new exploration targets in Triassic carbonates (partly reefoid) at depths below 3500 m, while Palaeogene clastics are prospective in the offshore.

The Fergana Basin is one of the more well explored areas in the FSU. However, new exploration targets are Palaeogene and Cretaceous clastics below subthrust nappes, at depths in excess of 5000 m.

A potentially significant oil discovery has also been made in the Carpathian Foredeep Basin (Fig. 2) in subthrust Cenomanian sandstones at depths below 4000 m. This opens new exploration challenges in the lower part of the Mesozoic sequence. However, the main producing formations are the overlying Cretaceous and Palaeogene flysch and molasse sediments.

Several other prospective structures have also been identified in the Polish part of the Carpathian Flysch Basin, where the main targets are overthrust structures in Upper Cretaceous and Oligocene clastics. The total estimated reserves for this basin are 125 million bbl of oil and 7.8 Tcf of gas (Cisek et al. 1992). The same exploration targets have been recognized in the Romanian part of the Carpathian Foredeep Basin.

In the last two decades, exploration activity in intermontane the Vienna and Pannonian basins resulted in several small oil and gas discoveries in predominantly clastic Mesozoic and Lower Miocene reservoirs.

New potential targets are deep (over 4000 m) Cretaceous stratigraphic traps below overthrust Palaeogene flysch units. In the Hungarian part of the Pannonian basin estimated gas reserves are about 10 Tcf (Gajdos et al. 1992). The gas has a high nitrogen and carbon dioxide content.

This group of basins in the FSU contains total remaining and potential hydrocarbon reserves of around 25 billion bbl of oil and 160 Tcf of gas (Figs 5–6).

The available data on the oil and gas reserves in the Eastern European intermontane and foredeep basin are not sufficient for a more detailed evaluation.

3 Ancient and young cratonic basins

Cratonic basins occupy the larger and less altered part of the continental lithospheric plates. Their characteristic features are a thick sedimentary cover, low deposition rates and a moderate heat flow due to relative tectonic stability. The inner and marginal parts of cratonic basins exhibit different patterns of tectonic evolution. In the early stage of geodynamic evolution, rift plate separation is predominantly in the inner part of the basin, followed by plate collision and isostatic mass adjustment (Khain et al. 1991)

This model explains the high concentration of hydrocarbon reserves in the central, graben part of cratonic basins (e.g. West Siberia and Timan–Pechora) and in reef occurrences along the basin margins (Pre-Caspian basin). However, not all cratonic basins necessarily pass through the complete geodynamic cycle due to the dependence on global tectonic evolution of continents.

Examples in the FSU are the Pre-Caspian, Volga–Ural, Amu–Darya, Timan–Pechora, West Siberia and Lena–Tungus cratonic basins, which produce more than 80% of the oil and gas in the FSU. Some of them are now in the mature stage of production (Volga–Ural), others are still at an early stage of exploration (Lena–Tungus), with the remainder at the peak of production.

In the Pre-Caspian Basin many undrilled prospects remain in deep pre-salt Devonian and Carboniferous-Lower Permian deposits, while post salt Mesozoic clastics are still at an early stage of exploration. The major part (80%) of the remaining hydrocarbon
reserves is concentrated in pre-salt carbonate reservoirs of four giant fields—Tengiz, Karachaganak, Astrakhan and Zhanazhol. In the northern part of the basin a new exploration target is Middle Devonian clastics, where light sulphur-free oil has been tested in Karachaganak at a depth below 5500 m. The pre-salt Palaeozoic carbonate sequence has a very attractive exploration potential in the northern part of the Caspian Sea (Fig. 1), where potential oil reserves are estimated at 10 billion bbl and gas at 180 Tcf. (Figs 7-8).

The West Siberian basin accounts for about two-thirds of Russian oil production and more than half of the gas production. The principal exploration target is Upper Jurassic–Neocomian sandstones; however, they are at a mature exploration phase, all big structures having already been drilled. Alternative plays are Cretaceous clastics in the north Yamal which is mainly a gas producing area, and Palaeozoic carbonates in the Newrol depression, where oil has already been discovered (e.g. Maloichinskoe). This basin still contains 50% of the FSU’s undiscovered gas reserves (Fig. 8).

The Amu-Darya basin situated in the southern part of Turanian platform is the second largest gas producing province of the FSU, after West Siberia, and contains significant gas reserves (Fig. 8) in Neocomian sandstones (Shatlyk Formation). A major accumulation is the giant Doulectabad–Donmez gas field in Turkmenistan. Several other large, predominantly oil fields (Urtabulak, Kokdumalak) have been developed and are on-stream in the Uzbekistan part of the basin. The reservoirs are barrier reefs of Jurassic age.

Several new discoveries have been reported recently in the large but poorly explored Lena–Tungus Basin located within the East Siberian Platform. The principal plays are Vendian and lowermost Cambrian limestones sealed by Lower Cambrian salt, as well as Riphean (Proterozoic) carbonate reservoirs in the south-west part of the basin. The exploration potential of the basin has still to be evaluated as much of the area remains undrilled. However, large fields have been discovered on the Nepa–Botuoba Arch with recoverable oil reserves ranging from 0.15 to 0.36 billion bbl.

The Timan–Pechora basin is situated in the north-eastern part of the Russian Platform, and extends into the Barents Sea. This basin is predominantly oil-bearing, 80% of the fields having accumulations of oil and/or condensate. There are exploration prospects over practically the whole of the stratigraphic sequence.
which ranges in age from Ordovician to Triassic, having a thickness of 10–12 km.

The main producing reservoirs are Middle–Upper Devonian reef carbonates and Lower Permian terrigenous clastics with carbonates. Commercial quantities of oil have also been obtained from Ordovician clastics, Silurian reefs and Triassic sandstones.

Further prospectivity is moderate, because most of the large structures have been drilled, some 200 fields having been discovered. The remaining potential and potential reserves are estimated at 10 billion bbl of oil and about 50 Tcf of gas, with the exploration targets in the offshore being Mesozoic clastics (Figs 7–8).

The Volga–Ural Basin occupies the largest part of the Russian Platform and is one of the oldest producing provinces in the FSU. The 10 km-thick Palaeozoic sedimentary cover contains oil and gas accumulations over a wide stratigraphic range, i.e. from Middle Devonian to Upper Permian. The bulk of the oil reserves are concentrated in Middle–Upper Devonian–Lower Frasnian reefs (Eifelian–Lower Frasnian), and Lower and Middle Carboniferous dolomites and clastics. The main gas reserves occur in Devonian clastics and Middle Carboniferous (Bashkirian)–Lower Permian carbonates. New exploration opportunities are limited, with the exception of the relatively less-explored Buzuluk depression in the southern part of the basin.

This group of basins in the FSU contains a remaining and potential reserve of about 160 billion bbl of oil and 2600 Tcf of gas.

The Polish part of the East European Platform has only a few small oil fields producing from Middle Cambrian sandstones at a depth of about 3000 m. Present offshore exploration has resulted in a few non-commercial discoveries in the south-eastern part of the Baltic Sea. The same reservoir, together with Silurian reefs are producing oil in the Baltic onshore of the FSU.

New exploration opportunities exist in the offshore extension of the Middle Cambrian play, where two oil fields have been discovered to date.

In the East European Moesian Platform several small oil and gas discoveries have been made. In the Romanian part of the basin, production is obtained from Mesozoic volcanogenic and terrigenous reservoirs, while in the Bulgarian part, potential plays are stratigraphical traps below a regional Jurassic unconformity. Future exploration prospects of these basins appear limited because to date, no new plays have been identified.

An analysis of the hydrocarbon potential of the FSU indicates that about 75% of the remaining oil and 60% of the gas reserves are concentrated in cratonic basins, 20% and 35% correspondingly in marginal rift basins, and the remainder in foredeep and intermontane basins (Figs 9–10).

Information available on the Eastern European basins is not sufficiently detailed to permit any conclusions regarding the remaining oil and gas potential.

Conclusions

This brief overview of the hydrocarbon potential of the FSU and East European sedimentary basins results in the following conclusions.

- The cratonic basins have the greatest potential for the discovery of new hydrocarbon accumulations. The Caspian Sea part of the Pre-Caspian Basin and the
northern part of the West Siberia Basin are considered to be primary exploration areas.

- In the rift group of basins new exploration plays are likely in synrift and post-rift depositional sequences. The Barents Sea and Kara Sea passive continental margins are the most attractive exploration targets.
- Although the foredeep and intermontane basins are largely mature as far as exploration is concerned, there are remaining prospects in the Okhotsk–Sakhalin offshore basin and in the Lena–Vilyui foredeep.

**References**


