OIL & GAS COUNTRY

Croatia

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Country Review Croatia

Hydrocarbon exploration history

Hydrocarbon exploration offshore Croatia commenced with the Jadran-1 well, drilled in 1970, and two years later in 1973, the Jadran-6 well made the first discovery – the Ivana gas field. This initial success was in the shallow clastic gas play in the northern Adriatic. Since then, 135 exploration and development wells have been drilled offshore Croatia, compared to more than 1358 exploration and development wells drilled offshore Italy. Croatian exploration success continued with the discovery of eight gas fields in the northern Adriatic which are now on-stream. Exploration activity in the central and southern basins of Croatia mirrored the exploration initiatives offshore Italy and focused on the Cretaceous carbonate platform oil play. Whilst several wells have encountered oil shows, there have been no commercial discoveries yet. However, this same carbonate platform play has been targeted successfully offshore Italy, including the discovery of the Rospo Mare, Elsa, Aquila, Rovesti and Giove oil pools. Despite the generic similarities, the nature of the carbonate oil play offshore Croatia is significantly different from that on the Italian margin and requires high-quality seismic to successfully image the Triassic and delineate source kitchens, identify platform margin reservoirs, and support basin modelling to constrain the timing of charge. The lack of such high-quality seismic has hampered the otherwise valiant attempts to chase the Mesozoic carbonate oil play in the Croatian offshore. In 2013 Spectrum acquired 14,700 km of long streamer 2D seismic data, which is tied to an 8000 km dataset of 2011 reprocessed Italian 2D seismic data.

Oil & Gas Development in Croatia

Domestic oil and gas fields are situated in the Sava, Drava and Slavonia-Syrmia depression in the inland part of Croatia, and in the Adriatic offshore.

Country Key Facts

Official name:	Republic of Croatia
Capital:	Zagreb
Population:	4 217 807 (2016)
Area:	56,542 square kilometers (21,831 square miles)
Form of government:	Parliamentary Republic
Language:	Croatian
Religions:	Catholic, Orthodox, Muslim
Currency:	Kuna (HRK)
Calling code:	+385

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Government

The Republic of Croatia is a unitary state using a parliamentary system. The president is head of state elected to a 5-year term who appoints the prime minister. The government is headed by the prime minister, with 4 deputy prime ministers and 17 other ministers. Parliament (Sabor) is unicameral. The number of Sabor elected members can vary from 100 to 160. They serve 4-year terms. A second chamber, the House of Counties, was abolished in 2001. Croatia joined the EU in 2013.

Source: GlobalShift

Croatia's gas reserves total some 25 bcm. Average annual production stands at 2.8 - 2.9 bcm. Total annual consumption equals more than 3 bcm.

The Sava depression shelters some of the most significant oil fields in the Republic of Croatia – Žutica, Ivanic, Stružec, Jamarice, Lipovljani. Reservoirs containing hydrocarbons are mostly layered sandstones. This area also comprises the only present Croatian underground natural gas storage, PSP Okoli, obtained by injecting gas in the depleted gas reservoir of "a" series Okoli field.

The Drava depression is the region with the most important Croatian reservoirs of natural gas and gas condensate: Molve, Kalinovac, Stari Gradac, Gola. In addition to its abundance in hydrocarbons, it should be pointed out that there is a high content of harmful non-hydrocarbon components – carbon dioxide (CO2), hydrogen sulphide (H2S) and elementary mercury (Hg) – which is additionally complicated by complex laying conditions and very high temperatures. All these aspects require the application of the latest technologies and materials with the utmost care and a carefully designed approach to the development process on the Drava basin fields.

On the east side of the Drava depression, not far from Donji Miholjac, there is one of the largest Croatian oil fields – Benicanci. According to the latest considerations of how to further develop that field, it is likely that injection of natural gas into the upper part of its massive carbonate structure will be applied in order to enhance oil production. That will produce a large volume of free gas in the reservoir which will allow its use as a new underground gas storage area.

Three oil fields – Đeletovci, Privlaka and Ilaca – located in the Slavonia-Syrmia depression, in the vicinity of Vinkovci, are in the territory under occupation during the Homeland War. After the war and peaceful reintegration, the fields were successfully retrieved into the production system of INA-Naftaplin.

In spite of some recent exploration success by Industrija nafte (INA), which should slow the decline in domestic oil production over the medium term, there is little immediate prospect of major oil accumulations being found and developed.

Offshore natural gas is produced on two exploitation fields. These are the North Adriatic, comprising the gas fields of Ivana, Ika, and Ida, and Aiza Laura with the gas fields of Marica and Katarina. There are plans to develop new fields

- Ana, Vesna, Annamaria and Izabela - in the near future, and to start additional development works on the existing producing fields.

Gas production is on the increase as Croatia's offshore potential is exploited near to the border with Italy in the Adriatic Sea and new local onshore markets are also developed. Steady growth in Croatia's gas production is forecast.

Croatia launched a licensing round in 2014. Economy Minister Ivan Vrdoljak announced the country's intention to further open acreage for exploration, and hopes to 'secure several hundred millions of US dollars' from new contracts signed.

Source: Energyfiles.com, INA, First Break

Geological Overview Offshore

The Adriatic is the most prolific hydrocarbon province in the northern Mediterranean, with over 20 biogenic gas fields and a number of thermogenic oil fields in production. Exploration activity in the Adriatic, however, has been heavily skewed in the past between Italy and Croatia, such that whilst the Italian Adriatic is relatively well explored, the eastern Croatian margin remains comparatively untouched.

In the Northwest Peri-Apenninic Foredeep Province the compressional structures were formed from multiple Arcs that were generated during the Messinian to Late Pliocene tectonic phases. Thrust anticlines are the common and typical structural element in both areas. Externally to the front of the Arcs, incipient gentle anticlines were formed. In the foreland area, relatively unaffected by the Pliocene tectonics, stratigraphic and combination traps are associated with the Messinian unconformity or with the up-dip shaling out of sandy beds. Gentle drape anticlines are present in the North Adriatic Homocline, where the Pliocene-Pleistocene succession was deposited onto an eroded Mesozoic carbonate substratum.

The southern Durres basin contains many of the same compressional features. The Periadriatic Depression appears to be a series of sedimentary wedges ahead of thrust fronts, The Dinarides fold belt (east) is separated from the Italian Apennine fold belt (west) by the Adriatic foredeep. The wedges are affected by Messinian and Late Pliocene-Pleistocene deformation (westwards compression) with asymmetric folding and thrusting, either in the continuation, or independent of the Serravallian thrusts, but generally influenced by their reactivation.

In the peripheral zone, monoclines are the main structural elements and are related to paleorelief forms. Anticlinal and synclinal structures are present in the western part of the Periadriatic Depression. They are mainly linear, forming structural ranges with a south- southeast – north-northwest trend.

The Apulian Carbonate Platform represents a midway point between the two thrust sequences. The edge of the platform trends obliquely to the modern marine basin in the Italian Apennine fold belt. Oil and gas fields occur in both thrusted Mesozoic carbonate traps and gas fields also occur in Tertiary reservoirs of the foredeep sequence.

Source Rocks
In the Northwest Peri-Apenninic Foredeep Province, biogenic gas accumulations originated from the organic matter in the Pliocene-Pleistocene clays. Total Organic Carbon content, mainly consisting of Type III kerogen vary from 0.1-0.2% in the hemipelagic clays to 0.5-0.6% in the re-sedimented clays associated with the turbiditic deposits.

A minor contribution of thermogenic gas and condensates is locally present along tectonized trends, where intense fracturing allowed the vertical migration from deep Miocene and Mesozoic sources. Middle-Upper Triassic source rocks, deposited in a restricted shallow sea environment and characterised by marine Type II kerogen, generated a large part of the thermogenic oil and gas of the basin.

In the Southern Durres basin there organic matter is mainly disseminated in shales, which are encountered throughout the Serravallian-Pliocene section. They appear to contain predominantly gas-prone, terrigenous-derived organic matter, which has generated dry biogenic gas and early thermogenic gas, as well as small quantities of immature condensate.

All dry gas accumulations in Albania and the Falco 1 discovery in the Italian waters are derived from these source rocks.

It is geochemically proven that oil (and associated condensate and gas) accumulations found in the Messinian sandstones have been sourced from the shales of the Carbonatic Series of the underlying Ionian Zone. Oil has migrated from the underlying carbonate reservoirs to the Messinian sandstones through the direct contact with the top of eroded limestones.

Reservoirs
Within the Northwest Peri-Apenninic Foredeep four main reservoirs have been identified:

- Messinian-Upper Pliocene transgressive sand and gravel reservoirs, unconformably resting on a Miocene substratum
- Sandy beds in the thick turbiditic Pliocene formations in the eastern Po Plain Upper
- Pliocene-Pleistocene sands in the Adriatic Homocline.
- Sandy intercalations in the Pliocene-Pleistocene Clay Formations.

The main types of hydrocarbon accumulations that have been found in the South Adriatic- Durres Basin are as follows:

- Cretaceous – Mid Eocene shelf edge and platform carbonates
- Oligocene, Lower Pliocene turbidites, Miocene sands
- Pleistocene shallow marine sands
- Middle Triassic sandstones

Seals

In the north, the Santerno clays seal the basal coarse clastics of the Messinian-Pliocene succession. Interbedded clay beds provide the seal in all other reservoirs. It is noted that in some cases these sealing beds may be less than 1 m thick. It has been suggested that gas is actually lost through the seal and replaced by the continuous in situ formation of new biogenic gas.

In the Durres Basin all reservoirs are sealed by intraformational shales/siltstones. Lateral changes from sandy to argillaceous facies also contribute to seal capacity. In some onshore areas biodegraded asphalt residues have plugged outcropping reservoirs and form effective seals.

Plays

Several plays have been identified in the Northern area:

- Asti group of plays, typically with combined stratigraphic-structural traps (Upper Pliocene-Pleistocene) – most of the fields are located in the North Adriatic offshore.
- Porto Garibaldi group of plays, typically with combined stratigraphic-structural traps (Lower-Upper Pliocene) – some of the major fields in the south eastern Po Plain and in the adjacent North Adriatic offshore.
- Morro d'Oro Stratigraphic-Structural Play – several fields in anticline and stratigraphic traps in the Adriatic Arc onshore and offshore.

Geological Overview Onshore

Croatia is located at the crossroads of Central Europe, the Balkans, and the Mediterranean. It is a highly varied country with high mountains of the Dinaric Alps at over 1000 m to large river planes cut by the Sava, Drava, Kupa and Danube rivers.

Geologically the country is split into two main onshore provinces, the Pannonian Basin Province and the Dinarides. These areas are very different both in geographical appearance and in geological terms.

The Pannonian Basin is located within the arcuate Carpathian mountain chain that encircles the basin; this

chain joins the Alpine mountain system to west and the Dinaric mountain system to southwest.

The basin is internally segmented by the intra-Carpathian mountain ranges and basement uplifts, but its continuity at the Tertiary level is not disrupted (the Graz Sub-basin and Vienna Basin in Austria, as well as the East Slovakian Sub-basin in Slovakia and Ukraine and the Transylvanian Basin in Romania show geological continuity with the central part of the Pannonian Basin).

The Croatian sector of the basin covers some 26,000km² and is split into 4 main sub basins – Sava, Drava, North west Croatia and Slavonija. The Dinaride region is present just outside of the basin limits to the South west.

Structural evolution
The present tectonic setting of the Pannonian Basin Province is characterized by Palaeozoic-Mesozoic sedimentary successions deposited upon older metamorphic basement.

The basement blocks were assembled during the Paleogene by extrusion from the west along strike-slip faults and were mainly subjected to sub-aerial erosion during the Maastrichtian-Paleocene. During the Cretaceous compressive deformations were common in the basin, caused by the closure of the Tethys Ocean.

During the Middle Miocene, extensive strike slip faulting began leading to pull-apart basins which rapidly evolved into rifts. Extension rates of up to 200% are often associated with reactivation of earlier compressional faults. The time of rifting varied according to the location – basins in the north and west are inferred to have been rifting as the earliest.

Many of the Miocene extensional basins were initially starved, but were subsequently filled by two major deltaic systems prograding from the west, north and southeast (draining the Carpathians). Combined thickness of the Palaeozoic-Recent series exceeds well over 10,000 m. Thickness of the Neogene succession alone is reaching over 7,000 m.

Petroleum systems - Source rocks
- The deltaic sequences of the Pannonian system itself. The lower part of the sequence was generated in deep-sea and is considered a very good source for oil and gas. The upper part (deltaic complex) is rather gas-prone and it is suggested that it has never been buried

deeply enough to reach oil window. However, it is very difficult to separate the respective sources of hydrocarbons in the basin (Clayton et al., 1988).
- Late Neogene source rocks with type II and III kerogen content were deposited as marine or lacustrine clays and marls deposited in restricted lagoonal settings, TOC average 1–2 wt.% (up to 5 wt.%).
- Early Miocene siltstones and mudstones with kerogen type III are mature to over-mature and produce dry wet and gas condensate.
- Upper Triassic Kössen black shales and marls are considered the principal sources of oil and natural gas in deep systems.
- Dinaride sources are oil prone formed within carbonate and carbonate evaporitic sequences of the region with TOC values (up to 21.8%).

Reservoirs

The major reservoirs in the basin include:
- Triassic limestones and dolomites (porosity up to 38%).
- Cretaceous carbonates.
- Neogene series of the Pannonian Basin (virtually all porous sands within these successions may form reservoir units given good structural/stratigraphic position).
- Miocene-age, near-basement basal clastic bodies (conglomerate). The series represent an excellent reservoir (porosity values may reach up to 61%). Oligocene sands within the “Paleogene basins” (e.g. turbidites of the Kiscell Formation).
- Fractured metamorphic and igneous basement rocks of Precambrian-Palaeozoic age.
- Dinaride resevoirs are generally composed of carbonate with Reefoidal limestone of the Upper Jurassic, Bio-accumulated limestone of the Cenomanian, Onkoidal and oolitic limestone (Aptian-Albian) and Succroidal dolomite and dolomite breccia of the Middle Jurassic.

Seals

The most important seals in the entire basin are provided by intra-formational mudstones of pro-delta and delta-top mudstones. In majority of the fields, the argillaceous interval above the reservoir usually forms the sealing horizon. It may also be the source rock for the next reservoir. The Neogene series are considered as top seal to all older reservoirs of the Pannonian.

Seal rocks in the dinarides are formed of sediments of hypersaline lagoonal Sabkha facies (anhydrite, early digenetic dolomite) of Albian-Cenomanian age.

Plays

- There are five main groups of plays discerned in the Pannonian Basin, best classified according to their structural affiliation (majority of fields involve reservoirs at many stratigraphic levels).
- Miocene-Pliocene clastic and/or carbonate series draped over basement highs form the most significant play types in the basin (such play types are represented by post-rift compactional drape varieties).
- Fractured and/or weathered basement (highs) with or without Miocene basal conglomerate and sealed by Miocene mudstones form a very important group of plays (Play types 1 and 2 are sometimes found together).
- Miocene extension-related, tilted fault blocks containing reservoirs of various ages form an important group of plays (Pre-rift/Basement compactional drape).
- Inversion-related play types are found in the anticlines associated with reactivation of strike-slip faults and include Miocene-Pliocene clastic reservoirs.
- Syn-rift-related, Miocene sandstone series truncated and sealed by post-rift mudstones (this play type formally may belong to type 1 plays).

In general, combined structural-stratigraphic plays are most typical in majority of the fields in the basin. The above-specified types of plays are valid in all countries sharing the area of the Pannonian Basin.

Exploration history offshore

Exploration offshore Croatia started in the northern Adriatic in 1968 with the acquisition of 2D seismic data. The most recent discovery was made in 2008 with the Monte Della Crescia gas discovery (Italian Sector). The region has over 90 producing fields.

- First discovery offshore Ravenna Mare-Punta Marina (1960)
- In 1973 the Ivana gas field was discovered spurring further exploration in the region
- Six more major finds resulted (Ika, Ida, Annamaria, Ksenija, Koraljka and Irma) from 1978-1993.
- Largest oil discovery offshore – Elsa 1 (1992)
- Largest gas discovery offshore – Porto Garibaldi-Agostino (1968)
- Discovery success rate offshore, (2004-2013 70%) all-time 36.5%

Exploration in the Southern Durres Basin area has been much reduced due to a lack of data. There are currently 16 discoveries in the area (11 onshore, 5 offshore) with some yet to be fully appraised. Many structures are still unexplored in the central and western part of the basin, where gas-generating conditions are more favourable, increasing the possibilities for new discoveries.

Exploration history onshore

Exploration of the basin has a long history that dates back to the 1850s, when the first well was drilled near seeps in Croatia. Geophysical surveying techniques were also applied at an early date. Peklenica was the first well drilled in 1884 where oil was exploited through shallow mineshafts until the first well was drilled. In the period after the end of the Second World War till 1950, oil and gas exploitation at shallow depths continued.

During the 1960s, some 20 discoveries were made out of at least 170 New Field Wildcats (NFWs) drilled. During the 1970s, about 180 NFWs were drilled. They resulted in 19 oil and oil/gas, and 13 gas accumulations. During the 1980s, at least 124 exploratory wells were drilled. Of that number, 22 wells were commercially successful, pointing out to the increasing maturation of the area from the exploration perspective. During the 1990s, at least 62 exploratory wells were drilled, and 10 of those wells were ascribed as commercially successful. Seven wells were drilled from 2000 to 2008, which resulted in three gas and gas/condensate discoveries.

Intensified use of gravimetric data and introduction of seismic methods led to the new discoveries within the Sava Depression, like Bunjani (1950), Kloštar (1951) and Dugo Selo (1952) oil fields. The national oil company, INA-Naftaplin was established in 1952.

Since the early 1980s, at least 17,500 line-km of 2D seismic and over 2,460 km2 of 3D seismic were acquired in the areas of the Pannonian Basin, now-belonging to the Republic of Croatia. The main period of seismic activity occurred during the 1980s (> 11,350 line-km 2D). During the 1990s and from 2000 to 2006, over 6,100 km of 2D seismic and 2,460 km² of 3D seismic were acquired.

Source: Croatian Hydrocarbons Agency

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