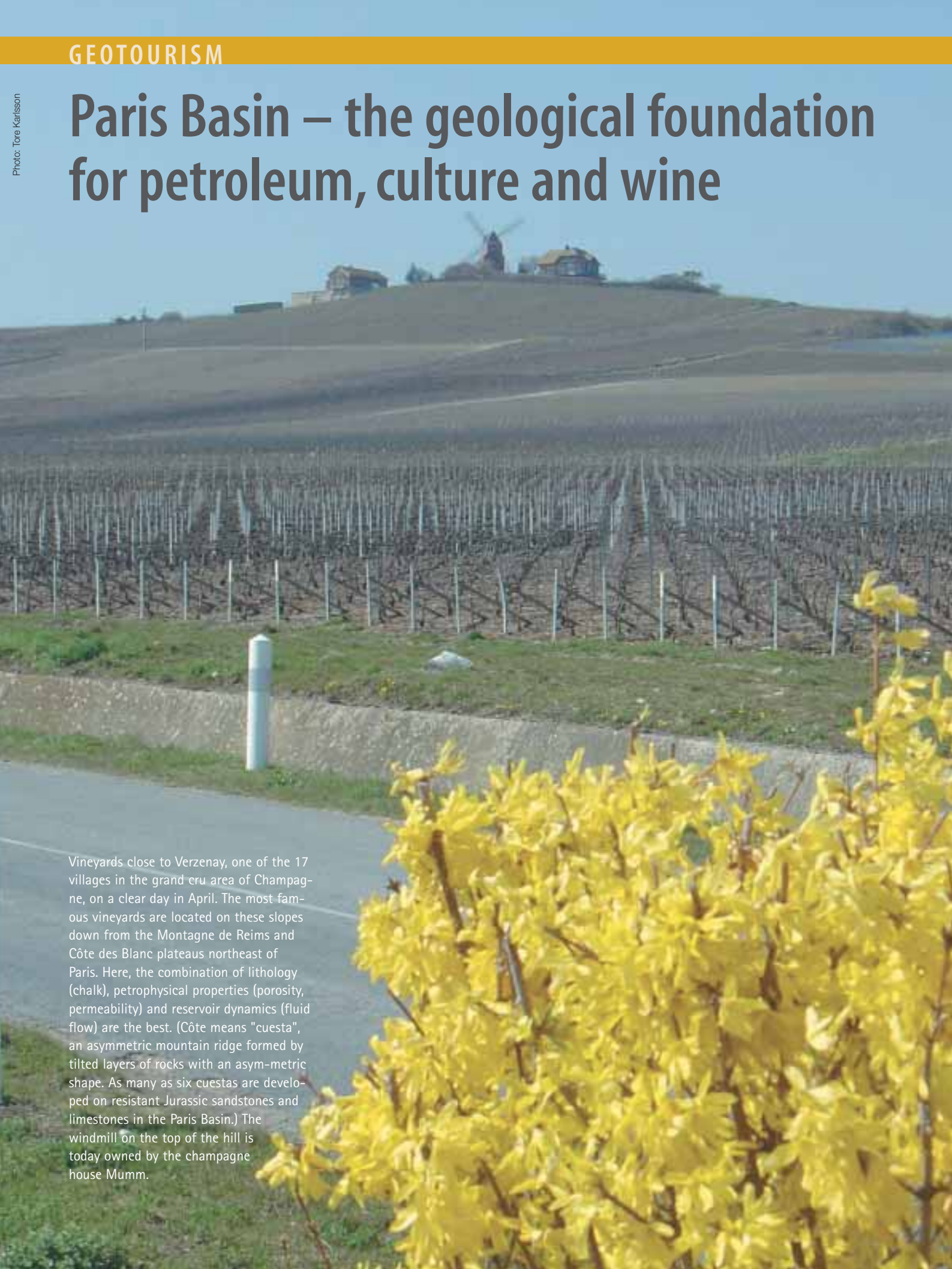
Paris Basin – the geological foundation for petroleum, culture and wine

Photo: Tore Karlsson



Vineyards close to Verzenay, one of the 17 villages in the grand cru area of Champagne, on a clear day in April. The most famous vineyards are located on these slopes down from the Montagne de Reims and Côte des Blanc plateaus northeast of Paris. Here, the combination of lithology (chalk), petrophysical properties (porosity, permeability) and reservoir dynamics (fluid flow) are the best. (Côte means "cuesta", an asymmetric mountain ridge formed by tilted layers of rocks with an asym-metric shape. As many as six cuestas are developed on resistant Jurassic sandstones and limestones in the Paris Basin.) The windmill on the top of the hill is today owned by the champagne house Mumm.

Photo: Tore Karlsson

The subsurface of the Paris Basin has yielded less hydrocarbons than oil companies had hoped for. On the other hand, the old rocks of this basin have made an excellent foundation for the production of the very best wines.

The Paris Basin has a multiple of geological resources: groundwater, geothermal heat, oil and gas. In addition, the soils made out of Jurassic and Cretaceous rocks are highly favourable for vineyards, chiefs of which are the districts of Champagne and Chablis in Bourgogne. The largest oil and gas fields of the Paris Basin (out of a total of 52) are shown in green and red, respectively.

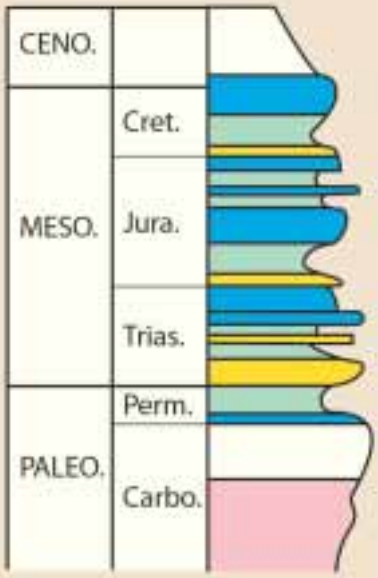
Nils Ræstad, Sagex

In the annals of geology, the Paris Basin has earned itself a respectable reputation through the groundbreaking work of the french geologist George Cuvier (1769-1832). Cuvier ranks among the founders of geology and was an early adopter of utilizing fossils from the Paris Basin to determine the respective ages of rocks.

In his meticulous work George Cuvier was in 1812 able to document numerous advances and retreats of the sea, which could be associated with major catastrophes extinguishing almost all animals and plants living then. Cuvier's work became a major scientific argument for the Catastrophists who battled with the Unifomitarians, the rival school of thought in the nineteenth century. Catastrophists believed that time molds the earth by means of sudden catastrophes. Uniformitarians believed that time works slowly, changing the face of the earth by long-continued action of the same processes that we observe at work today.

Today the Paris Basin's main claim to fame is as the foundation for the city of Paris, and for the vineyards yielding among others champagne and chablis, the vines growing on the fertile Tertiary and Mesozoic slopes east of Paris. As a source for energy, the basin is presently producing about 25,000 bbls/d of oil, plus providing geothermal heat through numerous wells. The lack of hydrocarbon exploration success in the 1990'ies has led to an almost total halt in new wildcatting. But the boom of the late 1980'ies where seismic vibrator trucks rolled down the Champs Elyseés is still fresh in mind.

Vibroseis trucks surveying down the Champs Elyseés in the 1980'ies.



Simplified stratigraphic column through the Mesozoic showing shales (green), sandstones (yellow) and carbonates (blue).

Mesozoic source and reservoirs

The Paris Basin is a crudely oval feature of about 140 000 km^2 in size (equivalent to more than 20 North Sea quadrants or 140 blocks). It has an extension with a long axis of nearly 500 km east-west and 300 km north-south, approximately coinciding with the drainage basin of the Seine river. Much of the area consists of flat valleys and low plateaus lying less than 100 m above sea level; eastward elevations reach about 350 to 400 m.

The Paris Basin is an epicontinental depocenter developed on a continental shelf invaded by marine seas from time to time. Successive depocenters are generally located to the east of Paris and thinning towards the edges. It is built on a crystalline basement and surrounded by crystalline highs of late Paleozoic age which is interpreted as the northern branch of the Variscan fold belt. The basin went through a series of uplifts in Tertiary times.

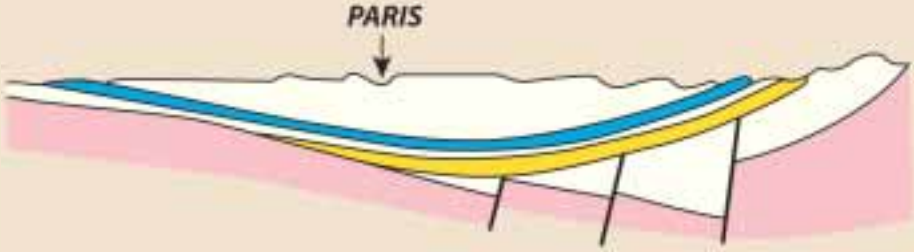
Marine sedimentation began in the Permian and continued into the Tertiary. More than 3000 m of sedimenatry rocks have acumulated in the basin center. This includes 150 m of Tertiary, about 1000 m of Cretaceous, some 1500 m of Jurassic and some 500 m of Permo-Triassic sediments. The Paris Basin is first of all an extensional basin (Triassic-Jurassic) which progressively evolved to a compressional one until the present day. The most important stress, which explains the present distribution of structural traps, was the Cretaceous-Eocene (Pyrenean) shortening. Several northwest-trending folds extend from the basin toward the English Channel.

Subsidence continued throughout the Triassic and the Jurassic, but decreased somewhat in the Early Cretaceous. By Late Cretaceous, the Tethys Sea to the south had transgressed and covered much of France. The extensive chalk deposits that outcrop in the Champagne district mark this transgression. Following a period of subaerial erosion, more episodic encroachments occurred in the Paleogene, with widespread Eocene beds overlain by Oligocene and Miocene units, a sequence of sands, marls, and clays.

The two main hydrocarbon reservoirs encountered in the Paris Basin are Upper Triassic Keuper sandstones and Middle Jurassic Bathonian carbonates (oolitic, bioclastic limestones), each of which has produced more than 40 % of the total production. Additionally, the Lower Cretaceous Neocomian sandstones and the Upper Triassic Rhaetian sandstones are also oil-bearing. Most of the gas produced comes from one single field (Trois-Fontaines) producing from the Middle Triassic Muschelkalk formation.

The Jurassic carbonate oil fields are complex oolitic, bioclastic limestone reservoirs. The largest, Villeperdue (42 million bbls recoverable), is a low amplitude, broad gentle structural nose dipping towards the northwest. Trapping is stratigraphic, with porous (8-18 %) micritic and concentric oolithis being replaced by radial oolite types with little reservoir quality. Current production is currently close to 1,900 bbls/day.

The principal source rocks for the hydrocarbons are several levels of Lower Jurassic Toarcian and Hettangian black shales that are still in the oil window. The Hettangian shales may have generated more oil than the Toarcian Black because they were more deeply buried and covered a larger area in the center of the basin. Migration



Simplified cross-section through the Paris Basin. Yellow and blue colour shows Triassic sandstones reservoir and Jurassic carbonates reservoir, respectively.

pathways are not a problem as the Hettangian is often in contact with Triassic sandstones through fault juxtaposition. The Middle Jurassic carbonates could have been fed vertically through faults.

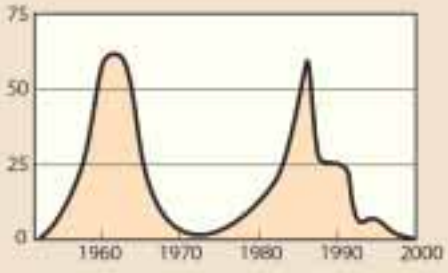
The seal of the Middle Jurassic carbonate reservoirs is the thick and wide spread Middle Jurassic (Callovian) shales. The presence of this very extensive shale interval is one of the possible explanation for having nearly no major oil accumulation above it in the center of the basin.

An 80 year history

The first exploration well in the Paris Basin was spudded in 1923 on a surface mapped anticline, but the well was dry.

It took another 30 years before serious exploration started up when a forerunner to Elf, SNPA, drilled a 3800 m deep stratigraphic test which proved the sedimentary thickness and had oil shows in Jurassic limestones and Triassic sandstones. Several small oil fields were subsequently discovered (first discovery was Coulommes in 1958 in Middle Jurassic carbonates) , but exploration declined and was just about halted by the mid 1960'ies with only 3 % of the wells leading to commercial production. The structural low relief, major velocity problems and complex and partly unpredictable porosity development in the Jurassic limestone reservoirs were contributing factors.

Then, with the improvement in seismic technology, exploration resumed in the mid 1970'ies with the major companies Total, Esso, Elf and Shell. Two large fields were discovered in the early 1980'ies, the Villeperdue field by Total (later operated by Coparex which became Lundin in 2002) and the Chaunoy field by Esso. These major discoveries lead to an exploration boom with 50 oil companies being active by 1987, but with limited success. There were small discoveries in the Triassic sandstones and Jurassic limestones.



Exploration wells drilled in the Paris Basin plotted as a function of time illustrates the two main exploration phases, in the 1960'ies and the 1980'ies.

As of today more than 800 exploration wells have been drilled in the Paris Basin. More than 240 million barrels of oil have been recovered from 52 fields. Cumulative production from Villeperdue and Chaunoy is 9,8 million tonnes (65 million bbls) and 5,8 million tonnes (40 million bbls), respectively.

An exposure of the chalk in the Montagne de Reims. The farmers of Champagne - long before the science of geology was established - through experience found out that the belemnite soil was to be preferred over the soil composed of the fossil remains of the sea urchin micraster. The belemnite soil is like a sponge, storing excess water for dry periods and with the ability to store heat.

Dom Perignon

Vine-leave imprints have been found in 60 million year old travertine in the Champagne district, and vineyards likely existed prior to the Roman invasion. The Emperor Domitian in AC 92 prohibited vine cultivation, an order later to be rescinded by his successor Emperor Probus, a much celebrated decision in the Reims district.

The monk Pierre Perignon - or Dom

Perignon - is often referred to as the "father of champagne". According to both French and other historians, however, Dom Perignon did not invent the *champagne technique*. Knowledge about how to make sparkling wine was probably developed in England around 1660. Wine on barrels from Champagne was received by the Brits who did the second fermentation in bottles. Not until around 1690 did the producers in Champagne start to make a sparkling wine, when stronger bottles became available to them.

It is agreed that Dom Periognon was an excellent wine maker, and before he died in 1715 it was common to ferment the wine twice to make it sparkling. It is also said that he produced a sparkling wine by a process of trapping carbon dioxide in the bottle and keeping the cork in place by a wire. His wine was soon appreciated by Louis XV for accompanying fine meals.

Wine on the rocks

In the Paris Basin there are two districts that produce excellent wines, Champagne and around the small town Chablis in Bourgogne.

In the Champagne district, some 100 km northeast of Paris, the preferred soil of the vine is chalk of the Upper Cretaceous which provides the best possible growing conditions. It is like a sponge and stores and returns heat and humidity, nourishing the delicate vine plants and producing grapes of distinctive character that partly account for the subtle composition of the finished wines.

The particular properties of the chalk also provide a uniquely nurturing environment. A network of chalk caves extends for more than 250 kilometres providing a haven of tranquillity for the developing wines. Deep in its welcoming recesses, they lie sheltered from light and noise and are protected from changes in temperature.

Three areas of Champagne produce excellent wines that qualify for the grand cru mark: Vallée de la Marne, Côte des Blancs and Montagne de Reims. Only three types of grapes are allowed for the production of champagne; Pinot Noir, Pinot Meunier and Chardonnay.

Chablis is named after a small town with only 2,700 inhabitants, but it is the birthplace of some very old wine production and the most northerly of the Bourgogne district. The oldest cellar in Chablis – which still stands today – was built by the monks in the 12th century. Today, Chablis has a reputation for making excellent, white dry wines.

The Chablis white wine is produced only from the Chardonnay grape. Grown on Upper Jurassic Kimmeridgian marl, this grape has unique mineral flavour. The vineyards in Chablis are also ranked by appellations and there are only 7 of them in the grand cru category.

Worth while a visit

The Paris Basin is the foundation for the cultural capital of the world and provides the soil for a wine surpassed by few. It is therfore well worth for petroleum geologists, reservoir engineers and alike to set their eyes on its fertile grounds while at the same time studying the rocks that provides both source and reservoirs for this oily basin.

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The geological information in this article ,including drawings on page 46, is to a large extent based on a scientific paper by J.Wendebourg and C.Lamiraux, Estimating the Ultimate Recoverable Reserves of the Paris Basin, Oil & Gas Science Technology – Rev. IFP, v. 57, No.6, pp. 621-629 on pages 46 and 47.

Tore Karlsson also contributed to this story.

Grand cru

The top ranking a vineyard and wine can receive both in Champagne, Chablis and in some other wine producing areas in France.

Photo: Tore Karlsson

85 year old Henri Goutorbe is still active. The Goutorbe house has been in business for three generations in Aÿ, one of the 17 Grand Cru villages in Champagne, where also the famous Bollinger house is located. The Goutorbes know their vineyards very well, as their original business was to produce and sell vine plants (pépinières). Henri Goutorbe took over the business from his father Emile after the Second World War and his son Emil joined him directly from school in 1970. The Goutorbes continue to grow new vines, but over the years the production of champagne has developed to an annual sale of 150,000 bottles. For the champagne production Goutorbe uses 70% Pinot Noir, 27% Chardonnay and 3% Pinot Meunier.

Photo: Tore Karlsson