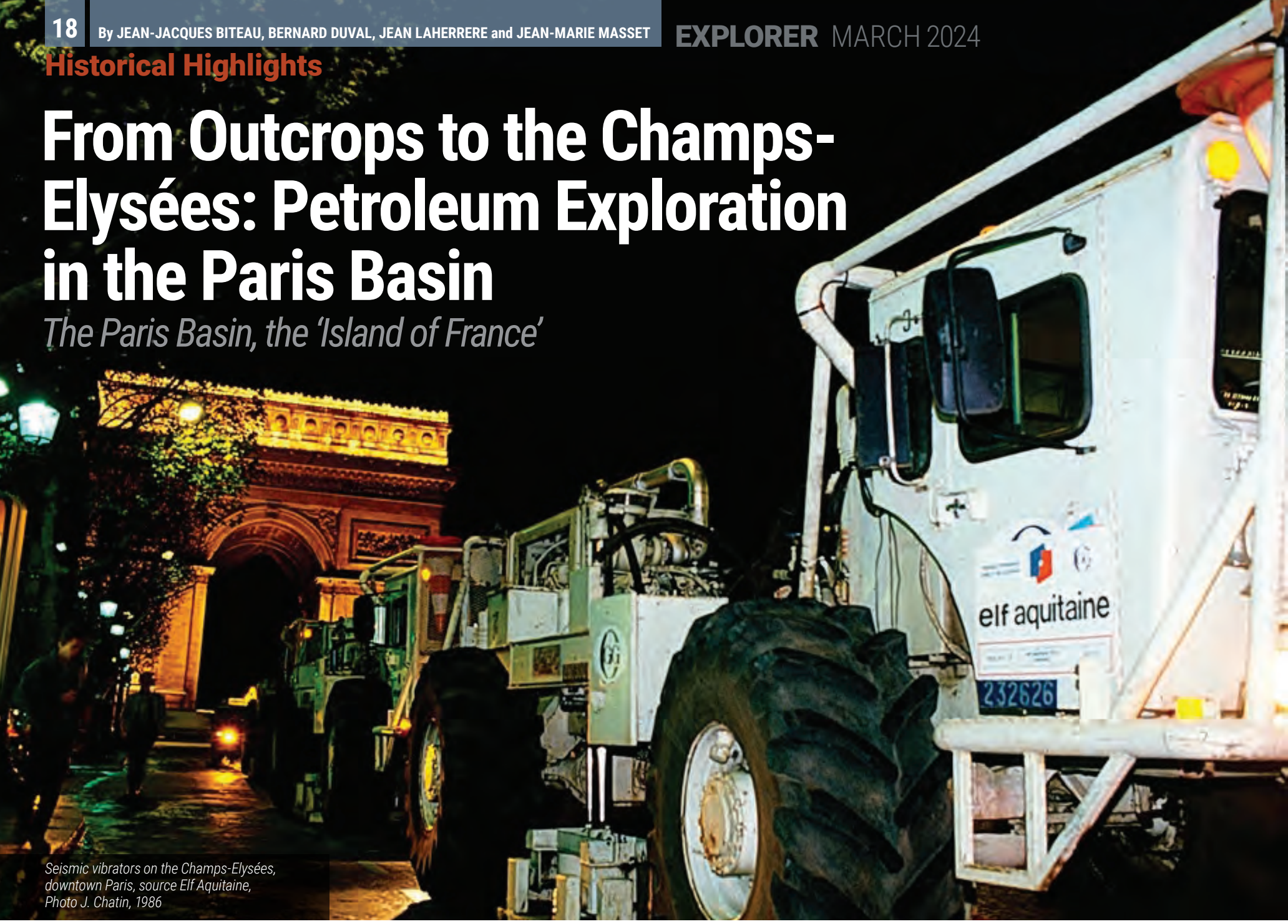
Historical Highlights

From Outcrops to the Champs-Elysées: Petroleum Exploration in the Paris Basin

The Paris Basin, the 'Island of France'



Seismic vibrators on the Champs-Elysées, downtown Paris, source Elf Aquitaine, Photo J. Chatin, 1986

The Paris Basin is one of the world's few basins that has been explored for petroleum for more than a century. Its exploration history is the second longest in France, after the Aquitaine basin. Despite modest 2P reserves of 345 million barrels of oil, 22 fields with reserves greater than 2 million barrels have been discovered and produced, thanks to the industry's sustained interest. It has a fascinating philosophy and strategy of exploration and its story traverses many well-known Paris locales and other settings famous for their tourist sites, cheeses (Brie, Coulommiers) and for Champagne.

The sediments of the Paris intracratonic, oval or "saucer-shaped" basin, start with units of the Carboniferous and Permian (the Sarre-Lorraine basin). They become younger from the Mesozoic outcrops at the edges to Tertiary/Pleistocene strata approximately at the level of the city of Paris, in the Île-de-France region (the Island of France). The maximum thickness of 9,800-11,500 feet is found in the depocenter in the Brie area.

Getting Started

The story began with a well drilled in the 1920s in Normandy (on the western side of the basin) on a surface anticline along the deeply rooted Bray regional fault. It had no real positive indications of hydrocarbons. Then everything of interest happened in the post-WWII period.

In 1951 the Bureau de Recherches Pétrolières, a state agency, contracted the French Petroleum Institute (IFP) for geological field studies and a complete gravimetric survey. The elements of the petroleum system, a concept established later in the 1980s by Alain Perrodon, Gerard Demaison, Leslie Magoon and Wallace Dow, were anticipated by this field work.

Bernard Duval, an engineer by training, was involved during the summer of 1956 as an intern in a field study conducted by Compagnie Française des Pétroles, now TotalEnergies. He and a team of three geologists studied outcrops all around the basin margins under party chief Jean-Marc Aymé. The work consisted of establishing a finely tuned stratigraphy (a practice new to Duval) and rock sampling for laboratory analysis, mostly from quarries. His effort focused on the Dogger carbonates and the Liassic organic-rich formations including the "Schistes Carton," which was visible, for example, in the fresh trenches of a freeway under construction at the time. It was a thankless, tedious job indeed.

France geological map, source Bureau de Recherches Géologiques et Minières (after BRGM)

Seeing him work passionately during a field visit, the chief of the Basin Studies Department, Jacques Dupouy-Camet, who was to become the exploration vice-president of the company, said to him, "My young friend, if you can withstand and even enjoy so much what you are doing here, so different from the grandiose and eventful geology of your Alpine training ground, you will surely become a petroleum geologist for many years to come!"

The VP got it right.

Interpretation of the field studies and a gravimetric survey suggested that Jurassic reservoirs that were Dogger, Hettangian and Rhaetian in age, and a good Liassic source rock could be expected in the 11,500-foot-thick sedimentary series resting on the Paleozoic.

In the euphoric period of its Saint-Marcet probe in the Aquitaine Basin (see Historical Highlights, May 2022), Régie Autonome des Pétroles was granted the 7,300-square-mile Chalons-sur-Marne permit. Société Nationale des Pétroles d'Aquitaine, which had just discovered the Upper Lacq oil field, was chosen for the Lorraine permit in the easternmost area.

RAP conducted seismic surveys and drilled a stratigraphic test well in 1953. They drilled Courgivaux-1 on a supposed gravimetric and seismic anomaly with oil shows in tight series of Bajocian and Rhaetian ages. Some geologists familiar with the Paris Basin would recall that this well exhibited an extended summary of its petroleum plays. RAP came back to the

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Bray area in 1954, recognizing the 1000-foot downdip location of the 1920s well, and Pays-de-Bray-101 found oil in a lenticular Jurassic reservoir. It produced only for a couple of months.

Late '50s: First Wave of Discoveries

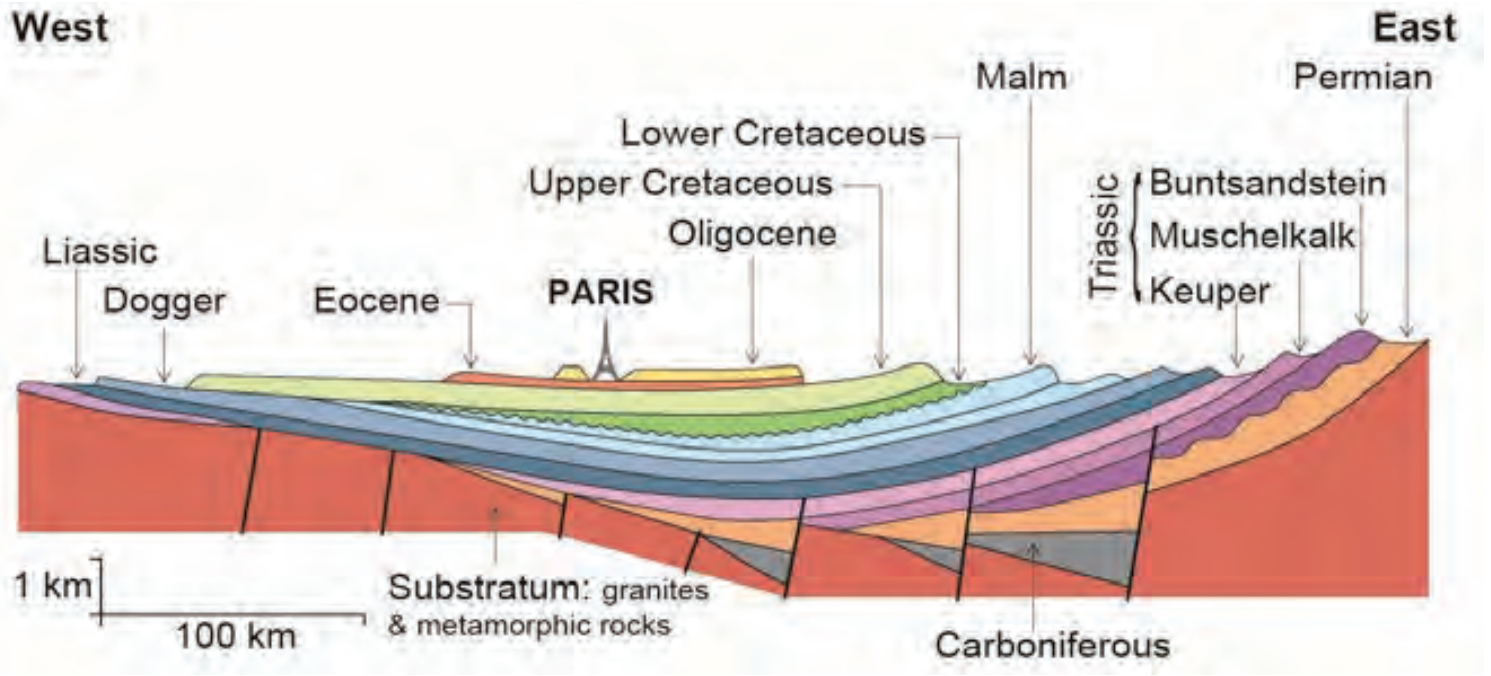
Fresh licenses were granted to newcomers, including Petrorep, southeast of Paris, and CFP and FROPEX-CEP in the southern part of the basin. SNPA decided to concentrate its efforts on the Triassic series. They found oil shows in Muschelkalk carbonate formations (Forcelles-1) and finally decided to partly relinquish their Lorraine permits in the eastern part of the basin.

This was a time for disappointments, but there was still a hint of optimism. Poor exploration results led the companies to calibrate near-surface seismic-velocity variations by using up-hole travel times from nearby shallow core holes. This enabled them to map structure more accurately by removing the effects of shallow low-velocity horizons.

This pragmatic approach became successful with modest discoveries in three plays. Dogger carbonates yielded field discoveries at Coulommes, 1958 (16 million barrels of oil); Chailly-en-Bière, 1958 (10 million); Villemer, 1959 (5 million), Brie-Chartrettes, 1959 (4 million) in the vicinity of Chailly; and other fields (less than 2 million). Saint-Martin-de-Bossenay (11 million barrels of oil) was discovered in 1959 and took off again in 2007 with horizontal wells and production of 1,000 barrels of oil per day.

Rhaetian siliciclastics hosted the Grandville field (5 million barrels of oil), discovered in 1958. Neocomian siliciclastics produced a surprise of reservoirs that were absent in outcrop. Château-Renard (1958) found wet Dogger carbonates but discovered unexpected shallow, oil-bearing Neocomian reservoirs in a pinchout play (7 million barrels of oil; 30 million including satellite fields).

A widely spaced seismic grid was completed in 1958 in the basin. However, the presence of seismic multiples, mandatory surface corrections and lateral velocity variations remained huge technical challenges. Defining prospects with subtle vertical closures of a few tens of meters (at best) was a recurrent problem.



Paris Basin regional geological cross section, source A. Perrodon, J. Zabek, Elf Aquitaine, AAPG Memoir 51, 1990

A Depth Record and a Second Wave

A two-decade period followed with no great success. Several drilling campaigns were completed, all leading to negative results except for one well whose deepening led to a small gas flow in Triassic sandstones (Trois-Fontaines).

Château-Renard field was put on stream then with look-alike satellites but efforts to find Neocomian pinchout reservoir analogs were all negative. Château-Renard remained unique.

In the Lorraine blocks in the eastern part of the basin, SNPA reinterpreted its acreage and drilled dry holes, among them Gironville-101 that was completed in the Carboniferous at 18,645 feet. That well has held the Paris Basin depth record since 1964.

In the early 1970s more fresh licenses were granted to newcomers, among them Esso REP which was trying to diversify exploration from its rewarding Aquitaine position. Potential targets were identified, particularly at Triassic levels.

The seismic problems, however, were still evident, and many failures were due to adverse surface conditions and very poor static corrections. For example, Esso REP drilled 20 dry wells on their Brie permit. A database covering static corrections was implemented by CGG to help solve those problems step-by-step.

Eurafrep applied for an area Elf-Esso had relinquished and discovered the Trois-Fontaines commercial gas field in 1982 in the Lower Triassic sandstones, 20 years after the Trois-Fontaines 101's small gas flow. Triton applied in the late 1970s for a license covering the Montmirail wells that had been drilled in the 1950s with oil shows. Herbert Brewer, Triton's senior vice president for Europe (and a former Esso REP chief geophysicist) used the recipe: go updip for a seal.

After several attempts at producing existing wells, Triton chose an updip location jointly with Total-CFP. The sequence of events from 1981 to 1986 leading to the discovery and appraisal-exploitation of the Villeperdue field illustrates the remarkable case of an unexpected Dogger stratigraphic trap containing 53 million barrels of 2P reserves. (See Chapter 15 of AAPG Memoir 54.)

A Vibroseis program concluded in mapping a transverse-faulted four-way closure of 4 square miles in area. VPU-1 was drilled in 1982 and completed in a Dogger reservoir for 430 barrels of oil per day. The appraisal drilling program showed by the end of 1983 that any significant four-way dip structure seemed to disappear. This left room for progressive reinterpretations to a westward plunging nose, determined from both well data and velocity corrections. Ultimately, an updip permeability barrier was inferred from additional wells drilled in the east and southeast parts of the field in 1986, as well as trapping enhancement by artesian hydrodynamic flow.

The flip side of geophysical difficulties like substantial velocity changes over short distances on gentle, low-relief structures is that there is always room for improvement, as well as for considerable tolerance in structural interpretation. Stratigraphic traps have been, and still are, often found fortuitously.

The Basin's 'Giant'

During the late 1970s, several companies increased investment in the Paris Basin, taking advantage of methodological improvements in seismic acquisition and processing, petroleum systems with Rock Eval to identify source intervals (pioneered by J. Espitalié), and modelling software developed by IFP. In 1981 Esso REP found Donnemarie, a modest oil field in the Brie

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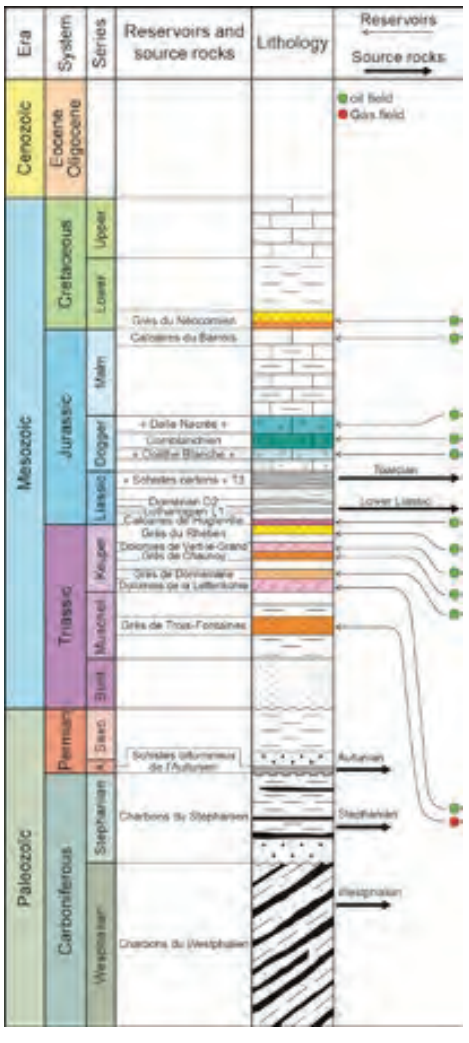
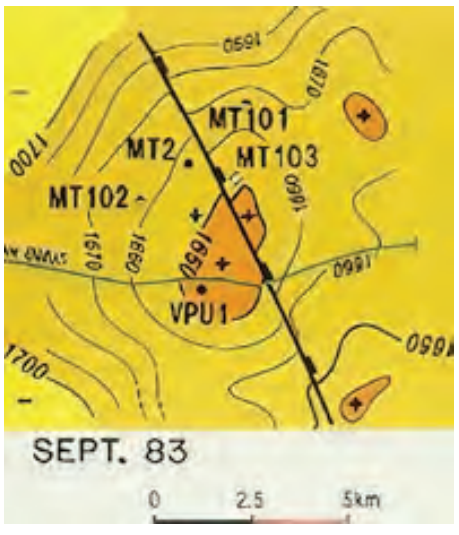
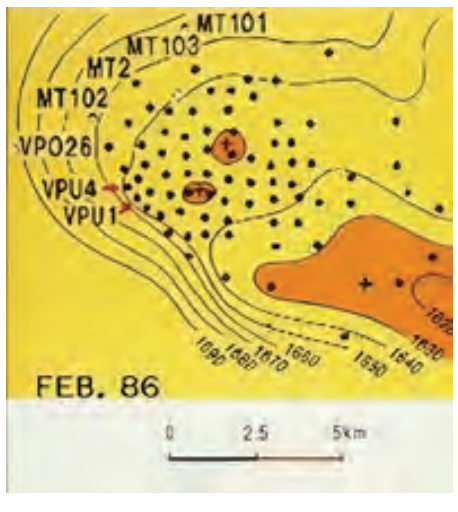







L'or noir jaillit au milieu des champs et Chaunoy-en-Brie à même sa famille Ewing

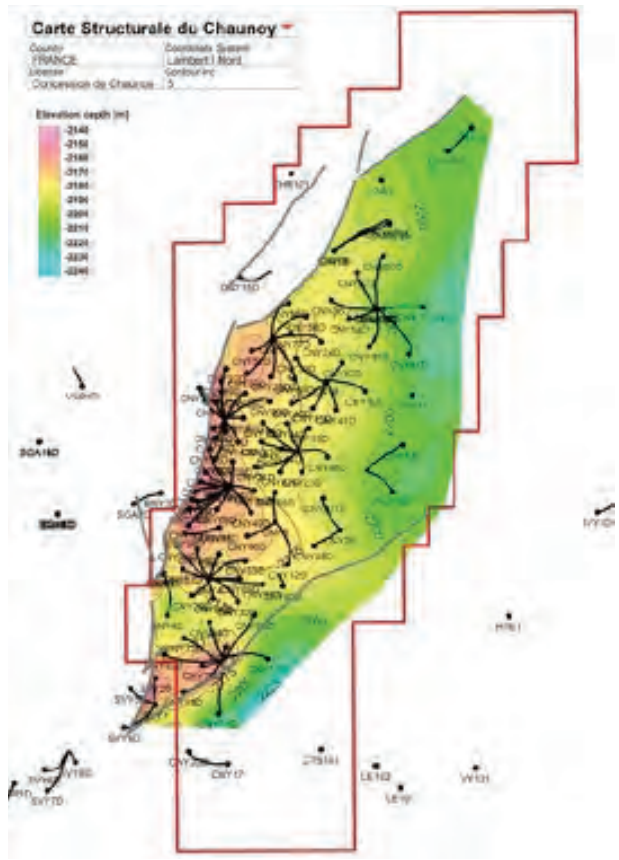
Dallas à 60 km de Notre-Dame...

● Des fermiers touchent des indemnités

● Certains maires bâtissent des châteaux en Espagne et leurs administrés se prennent déjà pour des Monégasques

Far left: Paris Basin stratigraphic and petroleum chart, source Géologie du Pétrole, J.J. Biteau, F. Baudin, Dunod, 2017. ***Middle:*** *Villeperdue, Exploration to Appraisals 1083-1986. From a closure to a nose helped by facies variations and hydrodynamic flow Source B Duval, P Arbin, Total, AAPG Stavanger International Conference and Exhibtion.* ***Above:*** *Chaunoy discovery, "Dallas near Paris" (Newspaper clipping from 1983, the height of popularity for the American TV show "Dallas," Vermilion LinkedIn post, 2023)*

Paris Basin, petroleum fields location map, source Géologie du Pétrole, J.J. Biteau, F. Baudin, Dunod, 2017



Chaunoy Oil Field top reservoir isobath (structure) map, source Vermilion REP

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region, in fluvial to deltaic, near-lake Keuper sandstones, sealed by intraformational shales of the same age. This drew attention to these reservoirs that had produced oil since 1967 in Chailly.

In 1983, Esso REP discovered Chaunoy Field on a northeast-southwest elongated anticline that is 9-miles long by 3-miles wide, with oil pay at the crest of the fault-related structure. This fault is difficult to identify on seismic, which might partly explain why the prospect was missed by the previous seismic grid that was spaced too widely. The anticline could be mapped accurately thanks to advanced new statics processing provided by Exxon's worldwide experts.

Chaunoy is the basin's largest field at 90 million barrels of 2P reserves. The size of the structure compensates largely for the 200-foot oil column. A great lesson from this discovery is that, once again in the profession, the alliance of technology, moving forward all the time, together with perseverance despite numerous discouraging failures, may well pay off in the end.

Serge Matesco, who oversaw Total's petroleum rights in France, said that a euphoric frenzy took hold of the industry in the early 1980s. It was triggered by the large discoveries and the hope for a fruitful marriage of advanced technology and new ideas. This led companies to quickly acquire dozens of permits. Fifty companies were present in 1987, including CFP Total which had an interest in 40 permits. The work commitments reached unacceptable levels and a lot of seismic and several wells followed with poor rewards. The craze for French petroleum acreage disappeared, paving the way for newcomers, mostly independents from the UK, who carried out parts of the ongoing programs.

As the excitement decreased, some companies persisted with modest but rewarding drilling success. Elf Aquitaine discovered Itteville Field, the last significant new field, in 1990. Its 2P reserves of 25 million barrels are reservoired in a Dogger stratigraphic trap, like Villeperdue. The main 2000s event was the significant increase of Champotran production and reserves (25 million barrels?) with contributions from southern extensions and a nearby eastern structure.

Seismic on the Champs-Elysées and Wells in Paris and Versailles

During the Late 1980s, Elf Aquitaine, Total and BP jointly applied for the large "Ile de France" permit covering the City of Paris and its suburbs, the only unexplored area. CGG completed a spectacular Vibroseis acquisition

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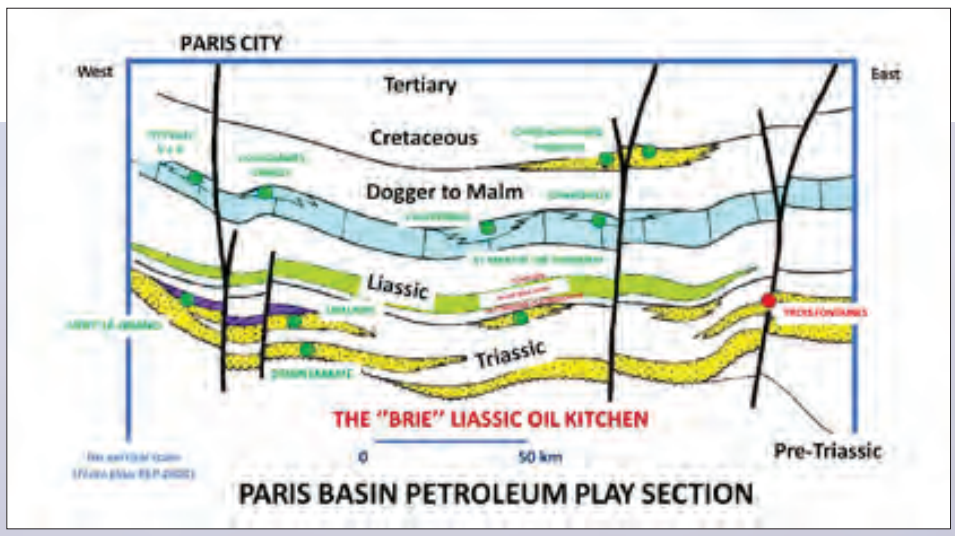
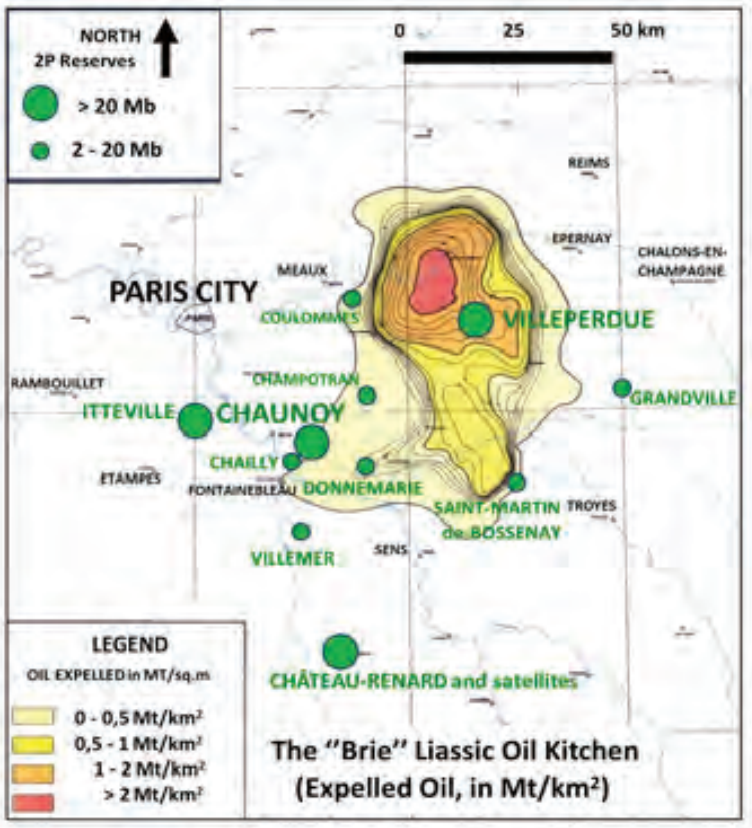
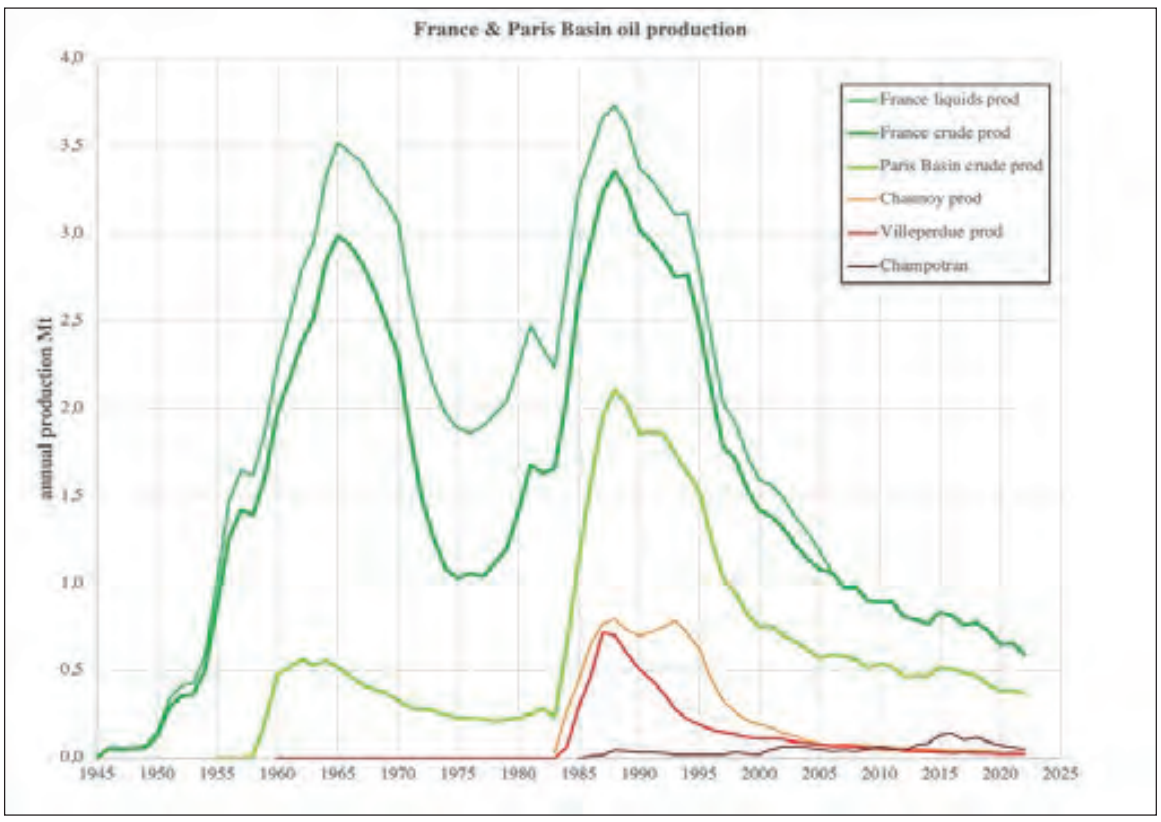


Right: Paris Basin Geopetroleum play section from Esso REP

Below: Ivry 101 drilling site, deviated well in Paris suburbs, source Elf Aquitaine, Photo A. Huneau, 1988



Paris Basin Liassic oil kitchen, source Elf Aquitaine in-house unpublished study, 1991. (1 million t/km2 = approx. 19 million barrels of oil per square mile)



Oil production statistics of the Paris Basin, sources Bureau Exploration-Production des Hydrocarbures and Comité Professionnel du Pétrole

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program in downtown Paris in 1986.

Ivry-101D was drilled deviated to reach a prospect right below urban buildings and produced Parisian oil for four years. Finally, in 1994 a delineation well was drilled at Itteville in the vicinity of the Versailles-Chevreloup arboretum using light equipment to reduce surface impact. It was dry.

The majors began to withdraw. ExxonMobil and Total-Elf Aquitaine sold their permits/concessions to Coparex (then Lundin, later International Petroleum), Geopetrol and Vermilion. These remaining operators as well as SPPE and Petrorep recorded successful exploration results nearby including Champotran-La Torche (Vermilion), La Motte-Noire Rhaetian and Merisiers Dogger (Coparex).

In the late 2000s Toreador and others began exploration for Liassic source-rock hydrocarbons with little success. The potential for unconventional hydrocarbons has been defined in the Liassic kitchen (Brie-Champagne) by geochemical data and the thermal history, but no resource estimate should be relied upon until pilot tests are carried out, which is so far unattainable due to the French ban on hydraulic fracturing operations.

Permian oil shales that were mined in the past in the small Autun half-graben in east-central France may also become unconventional oil and gas targets if there prove to be similar pre-Mesozoic grabens below the Paris Basin. However, France's political attitude towards shale oil and gas seems to be: "Non!"

A Last Wink at the Petroleum System(s)

The Paris Basin's 345-million-barrel 2P reserves are reservoired in 65 fields, of which 22 have reserves greater than 2 million barrels of oil. Only eight are greater than 10 million, and two are larger than 50 million. The top five are Chaunoy (90 million), Villeperdue (53 million), Château-Renard and satellites (30 million), Itteville (26 million), Champotran (25 million). The unique Trois Fontaines gas field has reserves of about 35 billion cubic feet. The Paris Basin's end-2022 total cumulative production is about 330 million barrels of oil. Current oil production is about 7,800 barrels of oil per day and declining. A considerable proportion of the traps (30 percent of the total reserves) have stratigraphic and hydrodynamic components (Villeperdue, Itteville, Château-Renard and satellites).

The three main reservoir-seal pairs (plays) include the Dogger/Oxfordian play, Callovian-Bathonian oolitic and bioclastic limestones with a complex facies distribution and diagenetic effects (cementation and fracturing). The main producing level at the top of the Callovian Dalle Nacrée formation is sealed by Callovian-Oxfordian marls.

The Rhaetian/Upper Rhaetian and Base Lias consists of regionally extensive fluvio-deltaic sandstones with fair to poor petrophysical characteristics. Lias and Rhaetian shales are the corresponding seals.

The Intra-Keuper Formations/intermediate seals play includes heterogeneous and discontinuous fluvial sandstones with good reservoir characteristics diagenetically modified by dolomitic cements. The Donnemarie, Chaunoy, Vert-Le-Grand, Chalain and Boissy formations are sealed by intra-formational shales.

The main proven source rock corresponds to the clay-marly levels of the Lias subdivided into three organo-types: Toarcian, Pliensbachian-Lotharingian and Sinemurian-Hettangian. Located between the Dogger and Keuper petroleum reservoirs, this is a very efficient hydrocarbon sandwich.

The source rock kitchen extends into the depocenter of the Brie area. Carboniferous layers are marginal sources in the Trois-Fontaines Muschelkalk gas field (where Storengy is the current operator) and the Forcelles Lettenkohle oil field (Replor, current operator).

The impact of the work done on the Toarcian, the historical reference for type-2 source rocks, has gone far beyond its geographical limits (although such detail is not well known even within our profession). It was studied intensely by Bernard Tissot, a mining engineer and longtime researcher at the IFP, a member of the French Academy of Sciences and an internationally recognized expert geochemist. This source rock served as the model for his pioneering work on the genesis of hydrocarbons through thermal degradation of organic matter, the characterization of kerogens and the kinetics of generation and migration. Last but not least, it played a key role in the development of Rock Eval, the well-known tool used worldwide by generations of petroleum geoscientists.

Jean-Jacques Biteau graduated from Ecole Nationale Supérieure de Géologie (ENSG Nancy) as a geologist engineer in 1977. He worked for Elf Aquitaine then Total (now TotalEnergies) at various exploration positions between 1979 and 2019. Biteau was Total's exploration vice president from 2009 to 2015. Now retired, he serves as associate professor at TotalEnergies Professeurs Associés.

Bernard Duval graduated in 1954 as an engineer from École Polytechnique and as a petroleum geoscientist from École Nationale Supérieure du Pétrole et des Moteurs (ENSPM, now IFP School). He received a degree in geology from Grenoble University in 1956. Duval worked for CFP (TotalEnergies) at various positions between 1958 and 1995 and was Total's senior vice president of exploration from 1985 to 1995. He is now associate professor at the IFP School and at TotalEnergies Professeurs Associés.

Jean Laherrere graduated in 1953 as an engineer from École Polytechnique and as a petroleum geoscientist from École Nationale Supérieure du Pétrole et des Moteurs. He received a degree in geology from Grenoble University in 1954. Laherrere served at CFP in various exploration positions between 1954 and 1991. He was the co-author with Colin Cambell of "The End of the Cheap Oil," published in 1998. He is the founder of ASPO France, the Association for the Study of Peak Oil and Gas.

Jean-Marie Masset graduated from ENSG Nancy as a geologist engineer in 1971. He worked for Elf Aquitaine, then Total, at various exploration positions between 1976 and 2009. He was appointed Total E&Ps senior vice president of geoscience-exploration-reservoir from 2000 to 2008. Masset is now retired.

Exploration Philosophy and Key Messages

Although a modest petroleum basin by world standards, the Paris Basin offers contrasting periods of discoveries and failures. It provides a rich spectrum of messages for explorers that reaches well beyond the expected regional interest. Major companies made most of the discoveries, but smaller independents like Petrorep and Vermilion, a Canadian company, are still active today.

Numerous dry wells drilled throughout the exploration programs bear witness to the necessity of persistent effort by the petroleum industry. This was encouraged, of course, by the need to relieve, even modestly, the level of French dependance on foreign sources of oil.

This reliance on domestic drilling success led the French industry to go through two main cycles of discoveries separated by a 20-year period of discouraging drilling endeavors. Only during the second cycle in the 1980s were two "Parisian giants" found. Their true size, at least for one of them, became apparent through an appraisal program and (to be frank) thanks significantly to serendipity.

Most of the structures have low relief. Combined with the complex problems of seismic statics due to the irregular thickness of a shallow chalk formation, this has impaired exploration. However, a message here is that such uncertainty leaves room for optimism when looking at this kind of play, thinking of the glass as half full rather than half empty.

Technology played its role and seismic has improved through time, for instance by using more powerful sources, more traces and a huge statics correction database. Evaluating this type of play in various mature areas of the world might provide strategic avenues at a time when the lack of prospective targets is becoming increasingly obvious.

(Historical Highlights is an EXPLORER series that focuses on the history of petroleum exploration and production. Topics broadly related to our work in the geosciences, the critical advances of science and technology, the key discoveries and the saints and sinners among our colleagues are all welcome. Narratives that illuminate the E&P process or its context in geopolitics and energy economics are encouraged. If you have such a story or know someone who does, please contact Matt Silverman, the series editor, at silverman_matthew@yahoo.com.)