

Discovery history of the giant Cusiana and Cupiagua oil fields, Colombia

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The Cusiana discovery in the foothills of the Llanos Basin of Colombia (Fig. 1) is the largest discovery in the 80 year history of the Colombian oil industry and the largest in the Western Hemisphere in the past 20 years. It should have been 'discovered' over 20 years ago and was virtually overlooked by the industry some 5 years ago. This is a brief overview of the Cusiana discovery and how the industry needs to be cognizant of the events of the past in formulating their exploration strategies for the future.

Exploration risk-taking by the industry from its earliest history to the 1970's made the major oil companies what they are today. But while the

industry has been successful over the past 20 years replacing production, it has not been successful in making giant discoveries.

Maybe the giants aren't there to be found. We in Triton believe many are still waiting to be discovered and that it is exploration mentality and management decision making that is the key to success.

Exploration means going where no one else has been before, that is, taking risks into the relative unknown — but in the frontiers of thinking. It doesn't have to be geographic frontiers. Unfortunately, over the past 20 years, exploration has been commercially driven and companies have become averse to taking risks on geological ideas.

All hydrocarbon provinces exhibit a step-like curve in cumulative discoveries over time (Fig. 2). Each step occurs when new ideas or new technology discover a new play, or when new ideas are applied to an old play and maximum wealth creation occurs when the largest fields in any play are found first.

Figure 3 shows the curve for Colombia and the different steps can all be attributed to the discovery of a new play. In the early 1980's, the steps related to the discovery of Cano Limon by Oxy and San Francisco by Hocol. If history was anything to go by, one would have thought subsequent exploration in Colombia would have fallen on fallow times; that is, going into a flat part of the curve. But Triton recognized the yet-to-find potential of the Llanos foothills trend and through the discovery of the Cusiana and Cupiagua Fields have opened up a new multi-billion barrel play fairway.

The Eastern Cordillera in Colombia were formed from the Mid-Miocene to recent inversion of a westerly verging Cretaceous rift system. The Llanos is the foreland basin to that fold and thrust belt and the Cusiana Field is associated with the frontal thrusts of that system (Fig. 4).

The 3 main reservoirs in the field are the coarse clastic, shallow shelf marine to estuarine Guadalupe and Barco Formations of Campanian and Paleocene

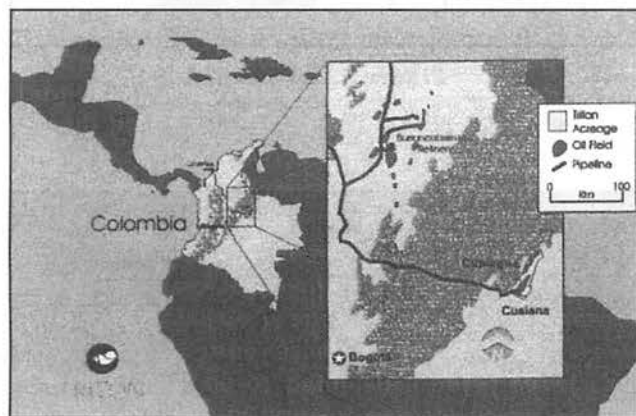


Figure 1. Cusiana location map.

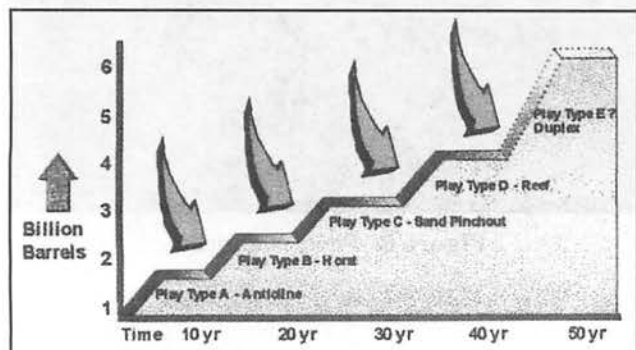
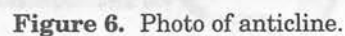
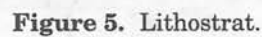
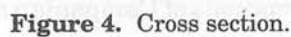
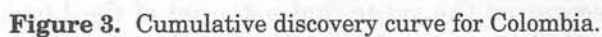


Figure 2. Typical cumulative discovery curve.



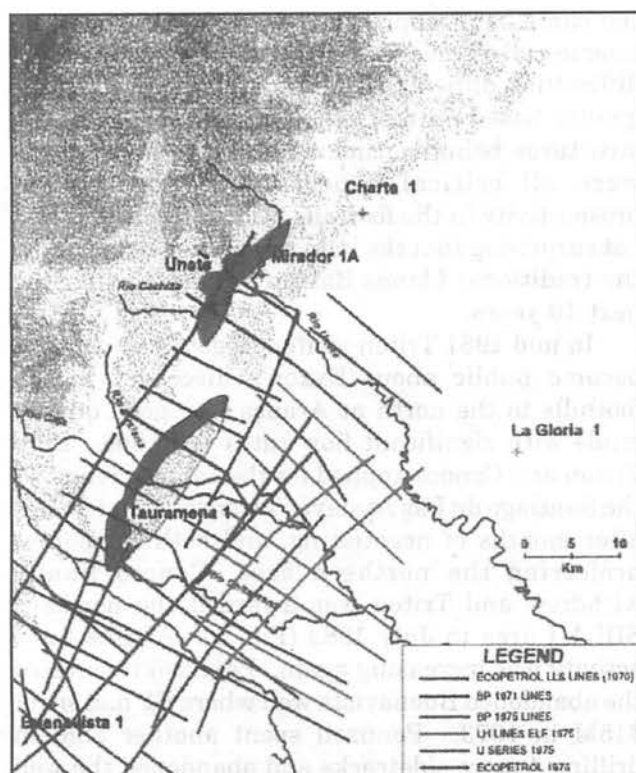


Figure 7. Foothills map 1970-1975.

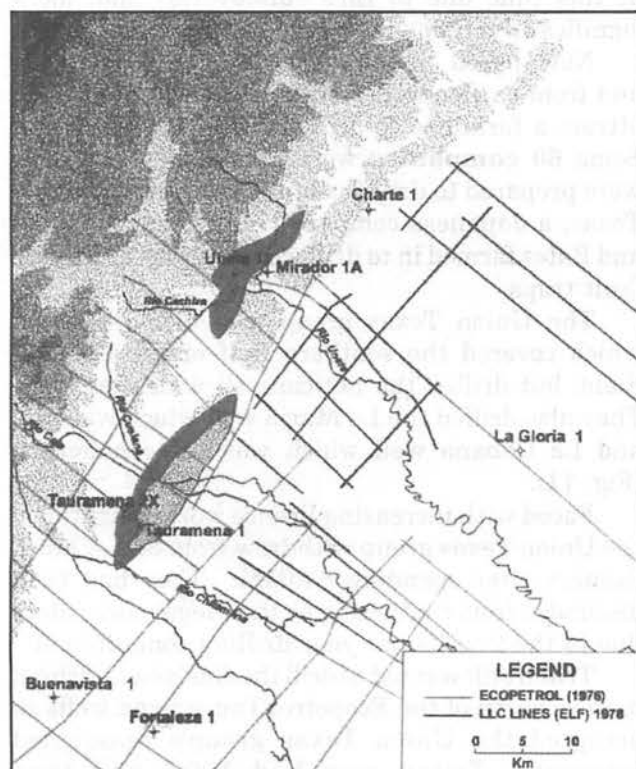


Figure 8. Foothills map 1976-1981.

age and which are overlain by the estuarine to alluvial plain clastics of the Mirador Formation of Eocene age (Fig. 5). The detailed geological aspects of the Field have been well documented in the 1995 October edition of the AAPG and I don't intend to duplicate that here.

It is the history of the discovery that is an important example for explorers to be aware of today.

The first well to be drilled in the foothills of the Eastern Cordillera was on a large surface anticline by Texaco in 1961 (Fig. 6). The Guavio well tested 500 BOPD but 2 offset wells were dry and the discovery was abandoned as sub-commercial. Also in 1961 Shell drilled the Tame well but that never reached the Eocene Mirador target.

In the early 1970's the Ministry of Mines attempted to stimulate exploration in the country and issued licences in the Llanos foreland and foothills to a number of companies who were attracted by these surface anticlines.

Figure 7 shows the Cusiana area in more detail and the Cusiana/Cupiagua fields as we know them now are shown in green. The lines represent different vintages of seismic.

Charte was drilled by Exxon who also drilled the Mirador well in 1974 just to the east of the Cupiagua frontal thrust.

BP did field work over the whole foothills area, acquired seismic over the southern end of the Cusiana feature and drilled the Buenavista well in 1973. Some \$15MM was spent by BP on this well which still failed to reach the target, so they dropped the licence. The Colombian National Oil Company, Ecopetrol, drilled Tauramena-1 in 1974 on the yet to be discovered Cusiana field but failed to reach the objective Mirador Formation for lack of funds and mechanical reasons. They also drilled Unete-1 in 1973 and really discovered what is now the Cupiagua Field. They recovered 35 barrels of 43° API from the Mirador but abandoned it as sub-commercial. It was evident from these old logs that the Mirador had a good SP and significant movable oil saturations.

But despite these early disappointments, Ecopetrol persevered with exploration in the area and redrilled the Cusiana structure with Tauramena-2X in 1976. The Mirador was eventually reached; but again, mechanical reasons and lack of funds, after over a year of drilling, meant only 10 bbls oil were reverse circulated from the Mirador.

At the same time, Elf was pursuing a different play in the foreland, acquiring seismic in 1975 and 1978, and they drilled the Fortaleza well in 1978 which was abandoned dry (Fig. 8).

By 1980, despite the activity of some 15

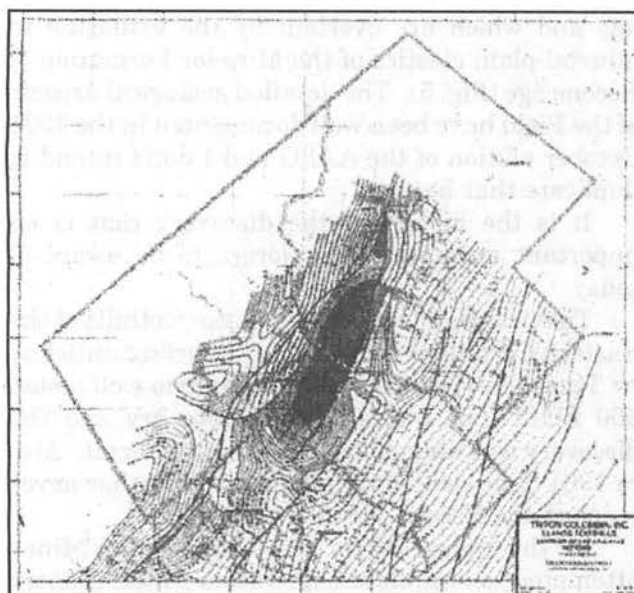


Figure 9. SDLA map.

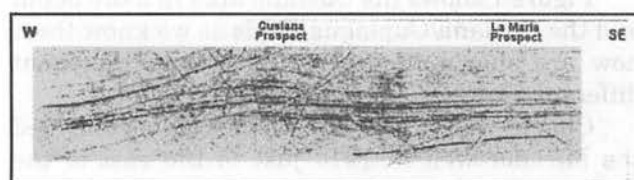


Figure 10. Seismic line T2.

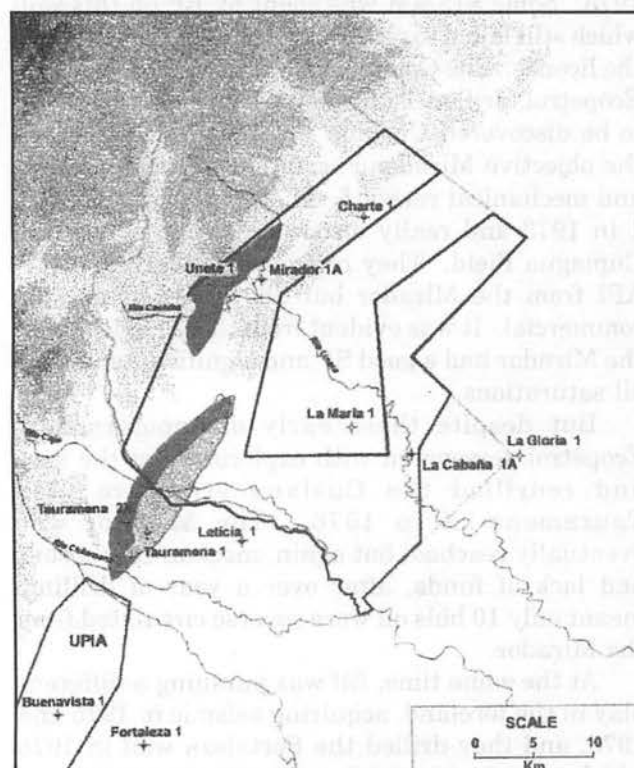


Figure 11. 1985-1986 reduced SDLA area.

companies and approximately \$80 MM spent, no commercial discoveries were made. Extreme drilling difficulties, difficult seismic imaging, poor reservoir quality based on test results, and the age of the structures being considered to be post-migration were all critical aspects that downgraded prospectivity in the foothills. Consequently, it was not surprising that the industry preferred to pursue the traditional Llanos Basin foreland play for the next 10 years.

In mid 1981 Triton visited Bogota just as news became public about Exxon's discovery in the foothills to the north at Arauca — good quality crude with significant flow rates @ 18,000. Both Triton and Conoco applied for the same acreage — the Santiago de Las Atalayas Licences 1 and 2. But after months of negotiating, and both companies preferring the northern area, Conoco finally withdrew and Triton was awarded the northern SDLA I area in July 1982 (Fig. 9). At this time, activity was increasing again. Pennzoil re-entered the abandoned Buenavista well where BP had spent \$15M in 1973. Pennzoil spent another \$8M in drilling 4 more sidetracks and abandoned the well in early 1982 at a higher TD than the original BP well.

Triton immediately acquired seismic over the SDLA Licence which highlighted the Cusiana feature (shown in Fig. 10 on the left of this line) and traditional plays in the east of the Licence (shown on the right). These prospects were antithetic fault traps and had attracted attention at this time due to Elf's discoveries and, more significantly, Oxy's discovery at Cano Limon.

Now, based on the mapping of this 1982 data and from earlier well results, Triton attempted to attract a farminee to drill the Cusiana structure. Some **60 companies** were approached but none were prepared to drill Cusiana. Eventually, Union Texas, a Japanese company, Impex, and Reading and Bates farmed in to drill wells into the antithetic fault traps.

The Union Texas group also took SLDA II, which covered the southern half of the Cusiana Field, but drilled the Leticia well which was dry. They also drilled the La Maria well which was dry, and La Cabana well which was sub-commercial (Fig. 11).

Faced with increasing licence work obligations, the Union Texas group withdrew from SDLA I & II licences after spending \$40MM. They had been dissuaded from continuing by their legal negotiators due to the 2 wells per year drilling commitment.

Triton still wanted to drill the Cusiana anticlinal feature north of the Ecopetrol Tauramena wells so accepted the Union Texas group's reassigned interest. Triton now had 100% and they renegotiated work commitments with Ecopetrol.

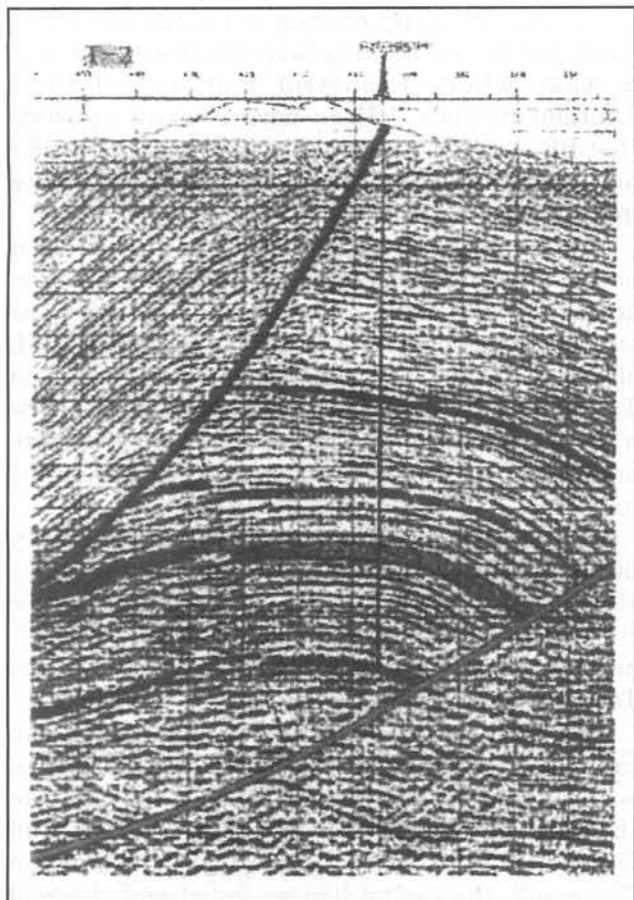


Figure 12. Cusiana 1 on seismic line.

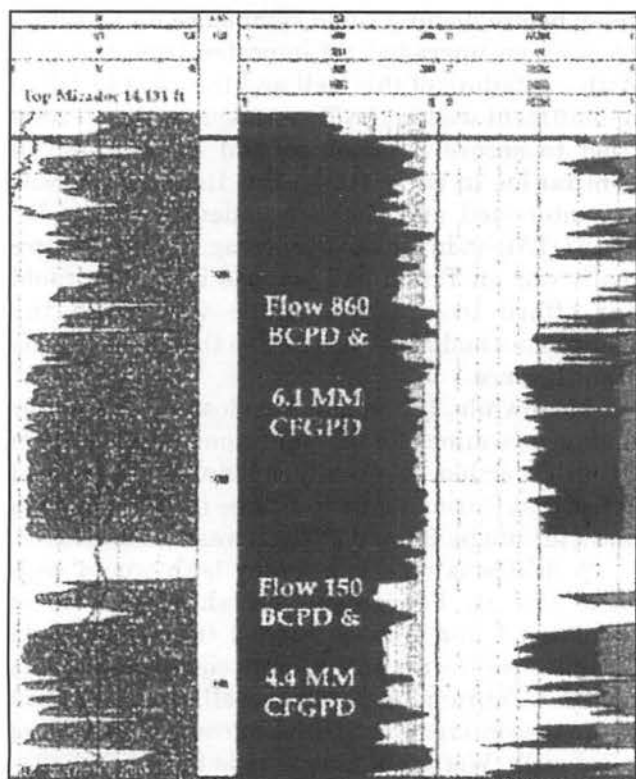


Figure 13. Cusiana 1 on well log.

Colombia was going through a difficult period — the Palace of Justice was stormed by the M-19 guerilla group in November 1985 and foreign investment was difficult to attract, oil price was down @ \$10, rigs were idle, cost cutting exercises had started, and the majors were cutting their worldwide exploration programs.

So Triton was able to renegotiate the work program commitments. The 4th year, 2-well commitment was exchanged for seismic reprocessing, 100 kms of new seismic and 55% relinquishment of the original area. Also, years 5 and 6 were reduced to 1 well per year given the difficulty of drilling in the area and that, to date, not one well had yet been completed within a year!

Beginning in May 1986, Triton contacted over **80 companies** seeking to get a well drilled on the Cusiana feature but not many companies were interested in Colombia. Technical concerns ranged from excessive well costs to poor reservoirs, the small area of 4-way dip closure and, most importantly, the timing of migration with respect to the very young age of the structure. But like Triton, BP and TOTAL were impressed by the fact that if there was late movement on the Cusiana fault, providing a seal as was the case in Cano Limon, then fault closure would be far larger than the small extent of a 4-way dip closure.

While the most likely outcome was relatively small reserves, the upside could be in the giant size. The partners were also convinced that moveable oil had been overlooked in the Tauramena and Unete wells; but very real concern on reservoir quality still existed, although the production from the Arauca field @ 18,000 provided some comfort.

So in early 1987, Triton eventually had their farminees, BP and TOTAL, who were prepared to drill the Cusian feature, each to earn 40% interest by sharing the costs of a well up to \$9 million.

Cusiana-1 was spudded at the end of October (Fig. 12) 1987 and progress was good until January when a terrorist attack delayed drilling by 2 months. The well was sidetracked beneath 13³/₈" and difficult drilling hampered the well through the Carbonera Formation. 9⁵/₈" was committed early and a 7" liner was set at the top of the Mirador Formation. Further progress in 6" hole was slow and the well was terminated close to the top of the Guadalupe Formation for fear of losing the well. Shows hadn't been encouraging and there was not much enthusiasm for testing since, after over 1 year of drilling and 3 revisions to the AFE's funds were low.

The first 3 tests were disappointing; mechanical problems and barite blocked valves were experienced with the test string. Few people wanted to continue but eventually, after 3 aborted tests in the Barco and Lower Mirador, the well flowed on

DST 3 from the Upper Mirador (Fig. 13).

Test results: 6.1 MMSCFD
860 bcpd

It was then decided to drill out a packer and retest the Lower Mirador which, with 5,000 psi drawdown over 2½ days, also eventually flowed gas and condensate. But, this well only proved the gas cap of the Cusiana reservoir and a further 3 years were to pass before the oil leg was proven.

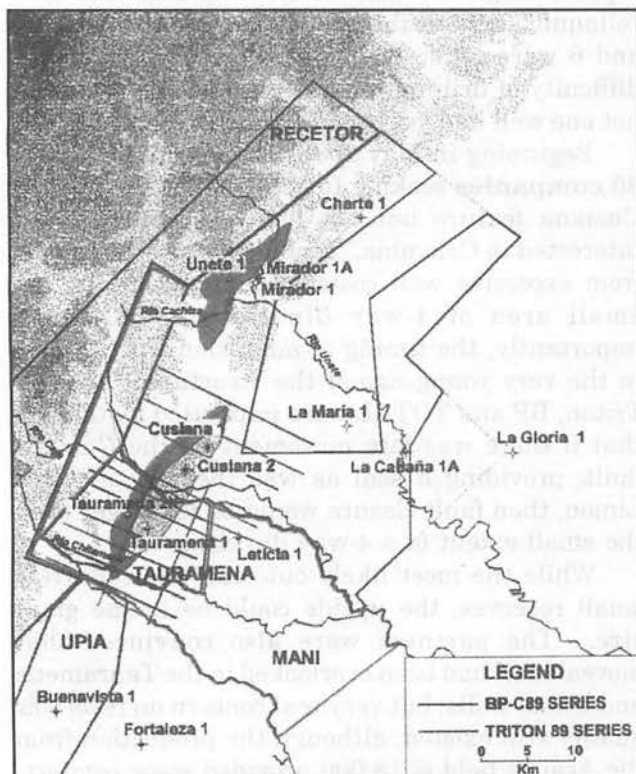


Figure 14. Foothills map 1988-1989.

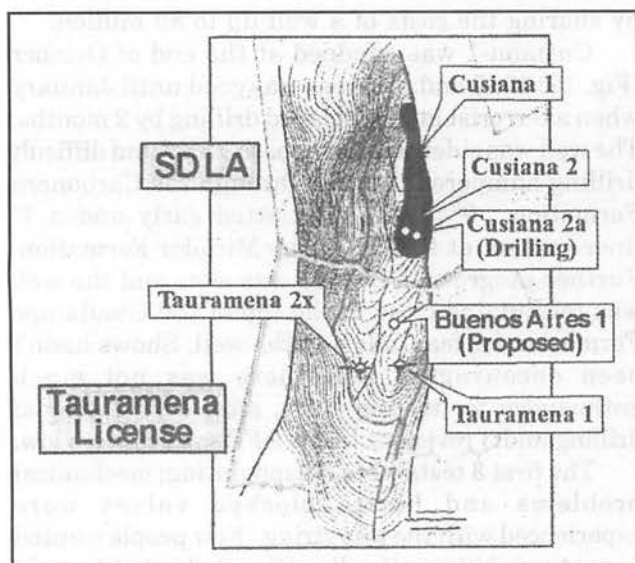


Figure 15. Cusiana structure map of Tauramena farmout.

During the early drilling of Cusiana 1, Triton wanted to licence the area to the south as protection acreage where Ecopetrol had drilled their Tauramena wells. Given agreement in principle that BP and TOTAL would join, Triton applied for and was awarded the Tauramena and Mani licences in July 1988 (Fig. 14).

But there was little support from BP in London or TOTAL in Paris to acquire this 'protection acreage' even though the 1st year commitment was only 50 km of seismic — a cost to BP and TOTAL of only US\$150,000 each! Despite the live oil in Tauramena 2X they thought Cusiana may only be a small gas discovery. They declined to participate and Triton continued in those licences with 100% interest.

Triton were running out of exploration money fast due to the demands of non-exploration activities elsewhere in the world. Also, Triton had to pay for their share of Cusiana-1 over \$9M which they hadn't anticipated and now they'd had to pay 100% for the Tauramena seismic.

Nevertheless, despite concerns over the capabilities of the rig, the Cusiana-2 appraisal well was spudded within 3 months and a few miles to the south of the discovery well (Fig. 15). Then, in December 1989, while setting 13¾" casing in Cusiana-2, the casing hanger failed and the well could not be retrieved and it was abandoned. A difficult meeting was held with Ecopetrol to explain the situation and that there would be a 6-month delay before drilling could commence on Cusiana-2A with an upgraded rig imported from the U.S. With the failure of this well and the need to drill a commitment well in the Tauramena licence, Triton tried to secure a farminee and approached 70 companies in early 1990. But the industry was not interested and couldn't understand why BP and TOTAL hadn't taken the acreage if the structure really was an Triton had mapped it. Triton could not afford to continue alone with both the Tauramena and Mani licences so they dropped the Mani Licence.

Meanwhile, Triton had been losing hope of ever finding a farminee for the Tauramena licence when BP in Colombia eventually convinced their Head Office that Cusiana must continue into Tauramena and a farm in by BP and TOTAL was consummated.

A deal was struck whereby both would each earn 25% in Tauramena for sharing costs of Cusiana-2A and Buenos Aires-1 (the Tauramena farminee well) with an option to equalize interests in SDLA/Tauramena farminee well) with an option to equalize interests in SDLA/Tauramena by drilling a 3rd well. Worthy of note here is that if Cusiana-2 had not failed for mechanical reasons it would have confirmed the oil leg in Cusiana and Triton

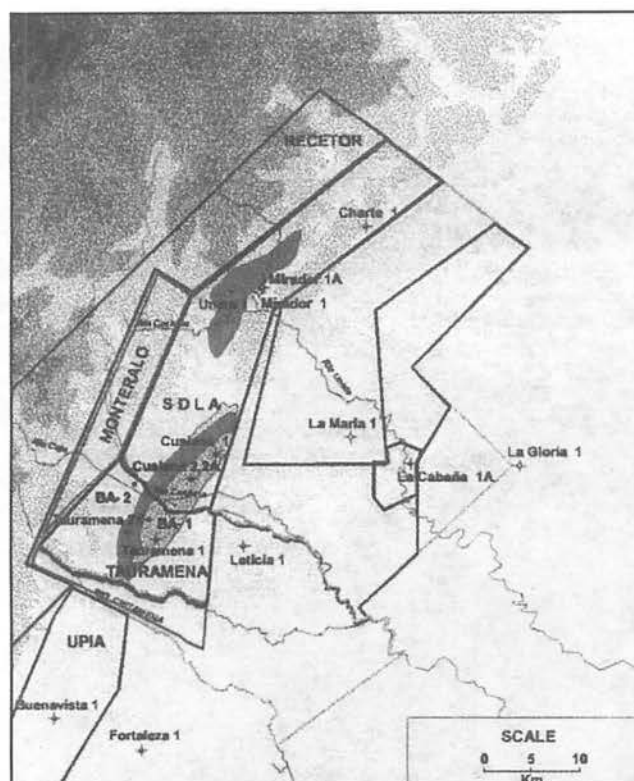


Figure 16. Foothills map 1990–1991.



Figure 17. Seismic line — Cupiagua.

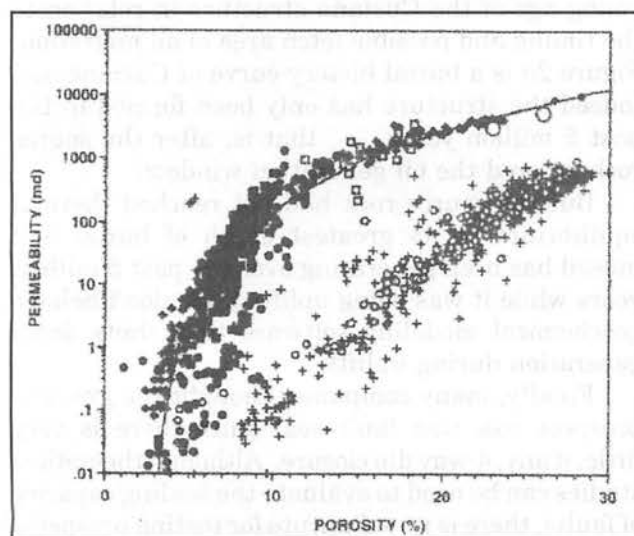


Figure 18. Quartz-arenite X plot.

would have had 100% of Tauramena. At the same time, BP and TOTAL paid dearly for not taking the opportunity to acquire this protection acreage some 2 years earlier on ground floor terms.

Another rig was imported and from mid 1990 to mid 1991 Cusiana-2A and Buenos Aires-1 were drilling simultaneously (Fig. 16). Major drilling difficulties were experienced on both wells but by July 1991, Cusiana-2A was the first well to penetrate an oil leg in the deeper Guadalupe reservoir and confirm Cusiana as a giant discovery.

During early 1991, TOTAL had been awarded the Rio Chitamina licence, previously the Triton Mani licence, and offered 50% to BP but never offered a share to Triton. This area has recently been incorporated into a unified Development Plan and Triton (with 9.6% NRI), BP and TOTAL (15.2% NRI each), and Ecopetrol have equalized interest in the 3 licences.

While activity throughout 1986 to 1992 had focused on the Cusiana structure, Triton had also tried to persuade BP and TOTAL to redrill the Unete structure. Some reconnaissance seismic was acquired in 1990 over this complicated structural area — once described as like looking for a needle in a haystack, when you couldn't see the haystack!!

But when Cusiana was confirmed as a world class discovery, detailing seismic was eventually acquired (Fig. 17) and the Cupiagua well was spudded in March 1992 as a redrill of the Unete well.

After nearly one year of drilling, Cupiagua-1 flowed over 600 bopd and 3 mmscf/d of gas from the Guadalupe. After mechanical problems and further testing, both the Barco and Mirador Formations flowed over 2,000 bopd and confirmed the giant potential of that field in early 1993. This field has recently been shown to be stacked imbricate thrusts of the 3 principal reservoirs and potentially a

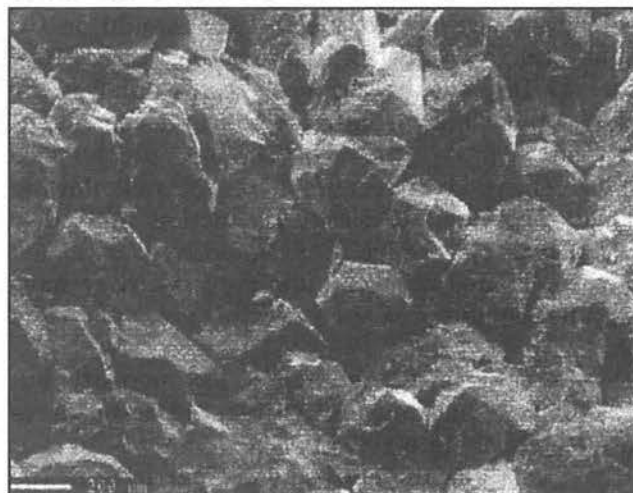


Figure 19. Slide of BA-3 — SEM of reservoir.

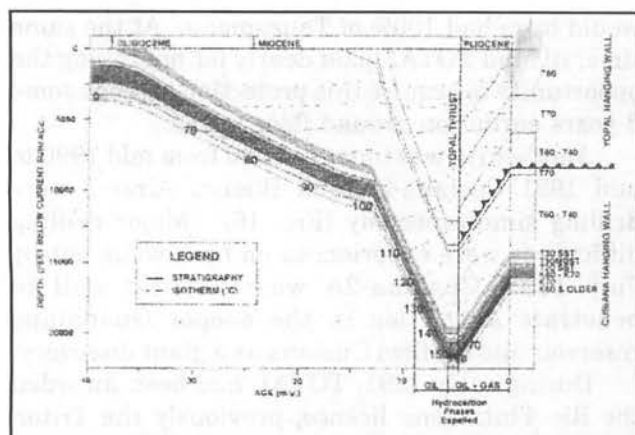


Figure 20. Burial history curve.

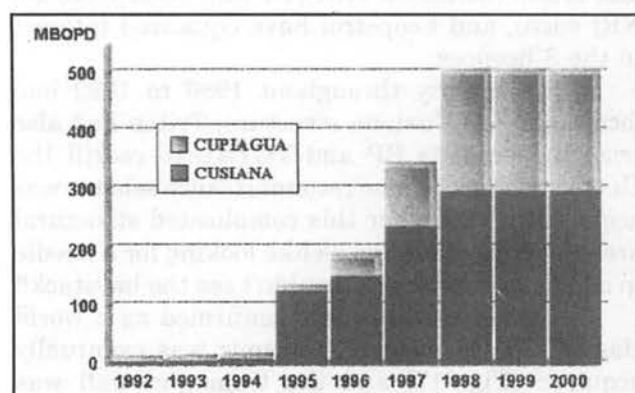


Figure 21. Production profile.



Figure 22. Photo of Central Processing Facilities.

cumulative oil column of 5,400'.

I would now like to address some of the critical geotechnical aspects that made the Cusiana prospect too risky for over 100 different companies — all of whom had the opportunity to farm in on 3 separate occasions — in 1982, 85 and 90.

First, the traditional straight line X plot of porosity and permeability predicted the lower Tertiary reservoirs in the foothills would be too tight and unproductive, mainly due to depth of burial. But despite the poor test results of the Unete and Tauramena-2X wells and the first 3 tests in Cusiana-1, the reservoirs have proven to be extremely productive with a recent well flowing 35,000 bbls/day!! Current production wells flow 12,000 bopd on average. Consequently, even though the sandstones are very low porosity, they have high permeability as shown in this cross plot (Fig. 18).

The reservoirs are in fact low porosity but extremely clean, quartz arenites and do not have any clay in the matrix (Fig. 19).

It seems as though the solid particles in the mud system of the early wells were forced into the

formations due to mud overbalance and would not be effectively flushed back out on testing. Solid particle size in current mud systems are now much smaller so that if they do enter the pore throats, they also come out much easier.

Second, explorers were also concerned at the young age of the Cusiana structure in relation to the timing and possible fetch area of oil migration. Figure 20 is a burial history curve of Cusiana and indeed the structure has only been formed in the past 5 million years — that is, after the source rock entered the oil generation window.

But the source rock had not reached thermal equilibrium at its greatest depth of burial and indeed has been generating over the past 5 million years while it was being uplifted. So don't believe geochemical modeling software that shuts down generation during uplift!

Finally, many companies thought the greatest prospect risk was fault seal since there is very little, if any, 4-way dip closure. Although theoretical studies can be used to evaluate the sealing capacity of faults, there is no substitute for testing prospects by the drill, particularly as the very late stage

compressional movements that formed the Cusiana structure are the same that provide fault seal at the Cano Limon field along the structural trend to the northeast.

To conclude, I'd now like to show you the proposed production profile from the Cusiana and Cupuagua fields — the largest discoveries in the Western Hemisphere in the past 25 years that over 100 companies had an opportunity to participate in.

Production is currently 185,000 bopd and will rise gradually over the next few years to peak at greater than 500,000 bopd by the end of 1997 (Fig. 21).

Figure 21 shows the Central Processing Facilities with a rig site in the foreground. The Buenos Aires-1 was drilled from this site right next to an existing pipeline route which you can just see here. What a great way to find a few billion barrels of oil — right under your nose!

I think you'll agree the Cusiana and Cupuagua discoveries were made possible by Triton's perseverance, determination, courage, expertise and vision for exploration risk-taking — an exploration strategy that we in Triton plan to continue for future similar successes.



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