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The Contribution of the Petroleum Studies Programmes at the UWI to the Oil and Gas Industry of Trinidad and Tobago

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Abstract: *A Petroleum Engineering Unit was established at the University of the West Indies (UWI), St Augustine in 1976 in the Department of Chemical Engineering of the Faculty of Engineering at the Government and Industry's request. Over the four decades, the strength of the Unit and interest in its programmes has varied as the oil price has fluctuated evolving into now an upstream Petroleum Studies Unit consisting of an accredited MSc programme in Petroleum Engineering (1981) and an undergraduate accredited programme in Petroleum Geoscience (2001). Some 429 students have graduated from the various Petroleum Studies programmes. The impact on the Caribbean, and Trinidad and Tobago (T&T) in particular, has been significant, for example the percentage of local Petroleum Engineers in the industry has increased from approximately 10% in the early 1970's to 85% in 2011. This paper outlines the Petroleum Industry in T&T, the history of the Petroleum Studies Unit at the UWI and concludes with how it has contributed to the industry.*

Keywords: *Petroleum Studies, Petroleum Engineering, Petroleum Geoscience, UWI*

1. Introduction

The Republic of Trinidad and Tobago (T&T) is in the West Indies and lies in the extreme south-eastern Caribbean Sea (latitude 10º 38' North, longitude 61º 24' West). It is a twin-island state near the southern-most end of the chain of Caribbean islands comprising the Lesser Antilles. Trinidad is located just northeast of Venezuela's coastline (7 miles at its closest). It is bordered by the Caribbean Sea to the north, Columbus Channel and Venezuela to the south, the Gulf of Paria and Venezuela to the west and the Atlantic Ocean to the east. She has a tropical climate, an area of 5,131 square kilometres (km) and a population of approximately 1.3 million. It is 3,500 km from North America (Florida) and 6-7,000 km from Europe (Spain-UK).

1.1 Oil in Trinidad

Oil has been produced in Trinidad for over 100 years. One of the first successful oil wells was drilled in the 1860's by Walter Darwent in the Aripero area. The Petroleum Industry is vital to the nation's economy and has provided the major proportion of national income for many years. However, there will be a day when production will dwindle, but as long as oil, gas and condensates are produced, petroleum will continue to play a dominant role in the T&T economy, and it is therefore important for nationals to be involved at all levels to ensure hydrocarbon production occurs for the longest while.

Oil and gas are found in the south of the island, and offshore on the northern, southeast and southwest shelves. Much of the onshore and Gulf of Paria production is heavy oil (<18º API), (Babwah et al, 2006). Some lighter oil and condensate is produced from the East Coast fields.

In 2010, Trinidad produced approximately 100,000 barrels (bbls) per day, although at its peak in the 1970's, it was around 240,000 bbls/day (MoEEA, 2011). Proven reserves (those that are certain) are estimated to be 750 million barrels and 'proven + probable + possible' (often known as 3P) reserves are estimated to be 2,700 million barrels. Possible reserves are those that have not yet been identified by drilling so are unproved, but maybe recoverable. However, unless some of the probable and possible reserves are found and developed or extensive programmes of Enhanced Oil Recovery are developed much of the proven oil reserves will be produced in about 20-30 years.

There is also a downstream sector where Trinidad has a refinery at Pointe-a-Pierre which at peak can

process over 200,000 bbls/day of oil. The country also has a pitch lake, one of the wonders of the world and 7,900 acres of unexploited tar sands.

1.2 Natural Gas in Trinidad

Large volumes of non-associated natural gas (gas with no associated oil) are found off the north and southeast coasts of Trinidad. It has been exploited since the 1960's (Ministry of Energy, 2011). The production and use of natural gas has increased in importance both in Trinidad and, generally, in the world's energy resource base. The National Gas Company (NGC) has the critical role to purchase and sell the natural gas to industrial users.

In 2010, the average daily gas production was 3.8 billion standard cubic feet (scf)/day gas, which is around 0.6 million bbls/day oil equivalent (6000 scf gas ≈1bbl oil). Thus for T&T in energy terms the production of natural gas is now much greater than oil (i.e., 6:1). Liquefied Natural Gas (LNG) is a major gas export of around 2.2 billion scf/day (BP, 2011).

Currently, the quoted proven reserves in T&T are around 14 trillion scf (BP, 2011). The 3P reserves of gas are at least 30 trillion scf and maybe as high as 100 trillion scf, which is within the world's top 30 known gas reserves (BP, 2011). Thus at the current production rates the gas reserves would be used in 12-14 years time. Some new gas (3P of about 0.5 tcf) has been discovered on-shore. So unless there is more in the subsurface, and the exploration activity finds significant quantities, there could be energy difficulties in T&T after 2020, although the recently proposed Government alternative energy strategies should make a beneficial contribution (MoEEA, 2011). Exploration is active and companies are hoping (expecting) to find commercial fields, particularly offshore.

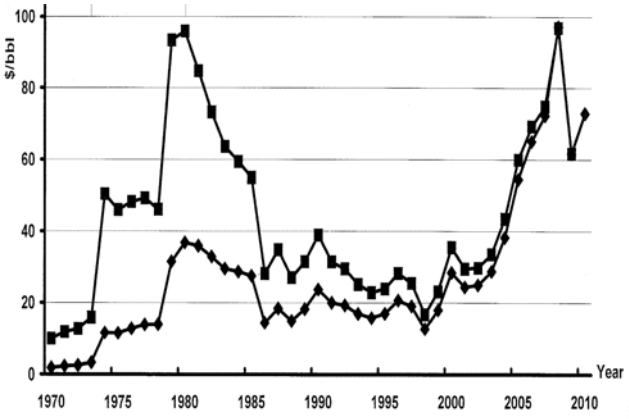
1.3 Local gas usage

Natural gas is used locally at about 1.6 billion scf/day for electrical power generation for local electricity, and in the manufacture of commodities such as iron, glass and cement and importantly methanol (≈17,000 tonnes /day), ammonia (≈15,000 tonnes/day) and urea (≈2,100 tonnes/day). Trinidad is the largest exporter of these products in the world. (MoEEA, 2011). In 2011, a melamine plant was opened to manufacture urea ammonium nitrate (UAN) and melamine using the urea and ammonia produced from natural gas feedstock at the Point Lisas complex. Some 60,000 metric tonnes per annum are to be produced. This diversification to use the primary products of ammonia, urea and methanol should help the creation of value-added goods (MHTL, 2011).

2. The Petroleum Economy of T&T

2.1 Oil price cycles

Since the seventies, the country has gone through a cycle of oil prices (see Figure 1). There were low oil prices in the early seventies, a boom in the early eighties, a recession in the late eighties to a slow, gradual increase in the nineties and a rapid decline at the end of the 1990's (oil being $9/bbl in February 1999). Then in 2007, a rapid rise to over $100 per barrel as a result of a worldwide economic meltdown due to greed, led particularly by the banking industry, to a relative stable $70-95/bbl in 2011.



Keys: •- in prices of the day, and -■- corrected to 2010 price.

Figure 1. Oil price fluctuation 1970-2010
Source: Based on BP (2011)

In addition, the investment climate has changed from being dominated by multinationals in the seventies to an emphasis on nationalisation in the eighties, and the divestment of state enterprises to create a climate for encouraging capital-intensive private investment. Many well known names such as Arco, Union, Amoco have disappeared as a result of numerous takeovers.

In 1989, the State-owned oil company Petrotrin, itself an amalgamation of a number of companies (Petrotrin, 2010), initiated a Lease operatorship programme, where the leases reactivated idle wells which were unprofitable or marginal for Petrotrin to invest in work over or stimulation activities. Then, a farmout programme was implemented to allow smaller producers to carry out exploration, development and reactivation programmes of farmed out acreage in South Trinidad. These leases and farmouts were primarily those of high geological risk and marginally economic for Petrotrin to produce, although smaller operators with lower related costs believed they could be profitable.

2.2 T&T becomes a gas economy

Up to 1999, the external dollar revenue in T&T was earned by oil exports, but the economy started to change in 1999 with the exporting of LNG. Oil has a fluctuating price market that is dependent on supply and demand, plus many other factors which keep the analysts talking everyday, thus the oil booms of the 1960's, late 1970's and mid 1980's, and recently the high-rise of oil price to

$147 bbl/day in mid-2008. Trinidad currently exports LNG (~2.2 bscf/day, ~46 thousand tonnes/day, ~17 million tonnes LNG /annum) (BP, 2011; MoEEA, 2011).

Gas is a much different business than oil with a greater inherent stability because contracts for gas chains are often for 15-20 years. Gas is thus long term, plus the LNG market has relatively stable prices, making the income stream to the T&T economy secure and relatively predictable. In 2011, gas is the major revenue earner for T&T, comprising some 85% of the value of exports (Central Bank of Trinidad, 2010) with exports of some 2.2 billion scf/day, via 4 trains. Even so, the tax and monetised revenues from oil and gas will start to decline at some stage after 2020, unless exploration finds more commercial hydrocarbons.

2.3 The future of oil and gas in T&T

New oil is only being slowly discovered, but some experts estimate the nation may be able to produce oil and gas for another 40-50 years. However, the evidence of reserves mentioned above suggests that the analysts may be optimistic. Nevertheless there is still a significant quantity of reserves, which if exploited prudently, could create a financial climate that should secure for its citizens a wealthy supply of the necessities for life for many years. The investment in, and expansion of, oil and gas-based industries could be used to diversify the national income and further strengthen T&T's economic base and prosperity, but it needs intelligent exploration strategies to find these reserves.

The expansion of the T&T gas industry has created a demand for upstream capacity, particularly geoscience, technical and business skills and competencies. Merely to meet the currently existing gas contracts in T&T, offshore development, production, and petroleum exploitation activities, staffing needs with these job skills are forecasted well beyond 2020. There is thus a strong demand for upstream capacity, preferably from the local workforce.

3. Upstream Petroleum Studies

3.1 Upstream Petroleum Studies

Upstream Petroleum Studies is concerned with the exploration, exploitation, drilling, production, processing and transportation of hydrocarbons (including solid, liquid or gas) from the earth, and all the related economic problems. The nature of these systems and operations dictate the reliance on the physical sciences, including geology, geophysics and engineering sciences, the latter contributing in such areas as mechanics, dynamics, heat transfer, fluid flow, mass transfer and thermodynamics.

3.2 Petroleum Geoscientists

Petroleum Geoscientists are those in the upstream petroleum business who assess acreage, identify exploration prospects, suggest possible drilling sites for potential hydrocarbons, appraise new discoveries, plan and implement field development. They also monitor the wells during production, and generally assist field management by teaming with petrophysicists, drillers, engineers and commercial units.

3.3 The Subject of Petroleum Engineering

Petroleum engineering involves the application of earth and physical sciences to the evaluation and exploitation of natural hydrocarbon resources. The dominant problems of the petroleum engineer are those of reserves estimates and flow and equilibrium in porous media, in well bores, in surface pipelines and in primary process equipment. The complexity of the hydrocarbon fluids, and the geological strata involved in flow in reservoirs and production systems raises problems requiring sophisticated numerical techniques for their solution. In the practical field, drilling and production difficulties continually pose new engineering problems requiring engineered solutions.

3.4 Petroleum Engineers

Petroleum engineers are employed in the engineering, supervision and management of hydrocarbon resources. These engineers face the challenge of ensuring the availability of adequate supplies of Petroleum and Natural Gas. The Petroleum Engineer is concerned with quantitative design and analysis in an economic and geotechnical framework, and cover the initial appraisal of a prospect, the interpretation of preliminary test data, the design of the drilling program, the choice of the recovery method, the design of appropriate process equipment and pipelines, as well as the development of future projects and exploitation policy.

Exploration sites are suggested by petroleum geoscientists, the petroleum engineers then find, evaluate, develop and produce the hydrocarbon reservoirs so that the fluids can be transported to a refinery for chemical and process engineers to convert them to useful saleable products. Thus, Petroleum Engineers are responsible for devising the optimum strategies for offshore and onshore hydrocarbon recovery. This exacting challenge calls for the use of the most sophisticated technology (including some of the fastest computers) for hydrocarbon resource development and management.

4. History of the Petroleum Engineering Unit, UWI

4.1 Background

The University of the West Indies was founded in 1948 at Mona, Jamaica as a College in special relationship with the University of London, to serve the British territories in the Caribbean area. It achieved full University status by Royal Charter in 1962, thereby becoming a degree-granting institution in its own right.

The formation of the independent state of Trinidad and Tobago in 1962 gave it the total responsibility for the country's natural resources. However, the

multinational companies dominated the oil industry, with the senior positions held by expatriates. Nationals of T&T were not directly involved in the engineering, supervision and management of hydrocarbon resources. Indigenous reservoir, petroleum, logging or drilling engineers were rare (Boopsingh, 1990, Higgins, 1996). Also as the fortunes of sugar declined, oil gained greater prominence in the overall economy.

4.2 Petroleum Education discussed at Cabinet level in 1975

In 1975, a Cabinet-appointed Committee examined the feasibility of a Petroleum Engineering Institute with the following terms of reference (Mohammed, 1996):

- To examine the feasibility of establishing a Petroleum Institute at the UWI, St. Augustine;
- To examine the facilities already existing at the St. Augustine campus that could be used by the Institute (i.e., Faculty of Engineering);
- To submit proposals for the creation of posts to accommodate specialist lecturers;
- To consider any other matter pertaining to the establishment of a Petroleum Institute, and
- To submit a cost for the project including projected recurrent budget.

The chairman of the committee, George Maxwell Richards (now President of the Republic of Trinidad and Tobago) stated, '…The establishment of a Petroleum Institute will provide the technical expertise, the trained manpower and the research input necessary to ensure both the prolongation of current patterns of production and refining and, more importantly, the development of new avenues for the utilisation of petroleum and its derivatives. The latter, especially, will provide the measure of industrial diversification essential to the survival of the industry and the National economy'. He concluded, '…The committee regards the establishment of the Petroleum Institute as a matter of the highest priority and strongly urges our early implementation of the project'.

4.3 Petroleum Engineering at UWI in 1976

The UWI's mission is to drive the development of the Caribbean Region through relevant training, research and community service. Since the Oil and Gas Industry is a controlling factor on the economy of T&T, it is paramount on the University to play its role in serving the industry.

In 1976, the University administration put forward a programme for petroleum engineers with a focus on the urgency of manpower needs, adequacy of training and costs. The Cabinet-appointed Committee recommended that funding should be provided by the government to initiate Petroleum Engineering training, initially through the operation of a Diploma programme followed by a three-year undergraduate programme leading to a BSc in Petroleum Engineering, so meeting the long-term needs for practicing Petroleum Engineers. The necessary infrastructure was put in place and the Diploma programme started in 1976, while the BSc programme started in 1978. Both were initially totally funded by the government of T&T (Mohammed, 1996).

The Diploma in Petroleum Engineering was run initially for three years from 1976 to 1979 as an interim measure and attracted mainly graduates from the oil sector, however it was suspended in 1981 when the graduates from the BSc programme became available for employment by the industry. It was reinstated in a modified form from 1986 until 1992. In total, twenty-six (26) students graduated from the Diploma Programme up to 2003 (Mohammed, 1996).

4.4 Effects of oil price fluctuations – The 1980's

The boom in oil prices in the early 1980's triggered increased drilling and exploration activities and encouraged new interest in the programme. A chair in Petroleum Engineering at UWI was funded by Trinidad-Tesoro in 1980 to be filled by visiting professors, and a chair funded by the Government of T&T was filled by Professor Percy Bruce who was the programme leader.

The development of a Master's programme was thus seen as an important step for this training of indigenous human resources. The Unit launched a Master of Science (MSc) programme in Petroleum Engineering in 1981. For the first few years, graduates found jobs very easily since most were on scholarships funded by the petroleum sector. However in 1986, there was a severe fall in oil prices causing the industry to decline, and as a result many companies stopped hiring and it became increasingly difficult for graduates to find jobs. Many of the graduates then pursued the Masters of Philosophy (MPhil) programme upon completing their first degree to wait for the industry to turn around. Faced with such poor job prospects, student interest in Petroleum Engineering as a career became low. Demand to enter the BSc programme slumped and as the University also had to deal with reduced government subvention, it was difficult to justify the resources to sustain the BSc programme so that in 1989 the programme was discontinued. Between 1980 and 1989, some forty-eight (48) students had graduated from the programme (Mohammed, 1996).

4.5 MSc programme changes in the 1990's

The early 1990's brought a change in government and new economic policies for the industry. Several tax incentives were put in place to create and encourage the capital investment needed for many potential projects in the industry. There was increased exploration activity through the Southern Basin Consortium involving multinationals such as Exxon, Total, Chevron and the Southeast Coast Consortium with Enron providing new opportunities for petroleum engineers, and a corresponding increase in activity of the service

companies associated with the petroleum industry, with many of these hiring petroleum engineers.

The response of the Faculty was to reach out to the industry through the establishment of an Advisory Group in 1989 to assess the best ways the University could serve the industry. Direct discussions with oil industry personnel resulted in the Unit revising the format of its MSc programme to a conversion type of training programme. As a result, the scope of the Master's programme was broadened, with a restructuring to give a flexibility in the options offered to suit the needs of the petroleum companies and the diverse backgrounds of individual students. Also, many of the petroleum engineers who had so far spent their entire career in the oilfield were moving into positions requiring managerial training.

In 1992, several new postgraduate programmes were introduced to deal with the shortage of local managerial manpower and better equip the industry to face the challenges of the country's petroleum resources. Offerings were introduced: MSc in Petroleum Engineering, MSc in Petroleum Management, MSc in Petroleum Engineering and Management and the corresponding Advanced Diploma programmes. The programmes were designed to equip the practicing engineer to competently handle contract negotiations with national or international companies.

The specific objectives of these management programmes were to provide a formal training for those who have been working in the industry and did not have specific Petroleum Management qualifications, and for training new engineers entering the industry for the first time. Industry was prepared to provide relevant expertise as visiting lecturers. This assistance even extended to the secondment of staff to the Unit. The high initial interest in these new programmes indicated that they were meeting critical needs in the industry. However as was the case with previous programmes, there was no sustained interest after 1996 (Mohammed, 1996).

The 1990's also showed a different trend because of the increased activity in the Petroleum Sector, perception of additional jobs in a growing Natural Gas Sector and the need for management training. Thus, although in 1999 the oil price dropped to $9/bbl which created a terrible depression in the industry generally, with companies being sold and the majors amalgamating (e.g. BP buying Amoco, and then Arco), The Republic of Trinidad and Tobago initiated LNG exporting facilities. As mentioned, this changed the economic scenario for the country completely to a stable income generation.

4.6 The TTMC Chair in 1998

In July 1998, The Trinidad and Tobago Methanol Company (TTMC), as part of an arrangement with the government agreed to endow a Chair in Petroleum Engineering for a period of 10 years in the first instance. This agreement is now being honoured by Methanol Holdings (Trinidad) Limited and has been extended to 2015.

The terms of the appointment included 'The Chair-holder is expected to provide significant leadership in developing an educational and research programme in Petroleum Engineering similar to those of other reputable academic institutions, and develop and maintain strong interaction with the oil industry to serve the needs of the Republic of Trinidad and Tobago, and where relevant the wider Caribbean. In addition to scholarly activities in the field of petroleum engineering, great emphasis also should be given to strengthen the University's co-operation with industry and to the development of strong industrial contact.' Richard Dawe from the Petroleum Engineering Unit of Imperial College, London, was appointed to the Chair and took residence in August 1999.

4.7 The introduction of the Petroleum Geoscience Programme in 2001

In 1999, the petroleum industry in T&T had industrial growth with the development of the LNG exporting business, but an aging community of petroleum geoscientists. As such, an injection of locally-grown graduates trained to the highest international standards was needed to fill professional positions. To address this requirement an undergraduate programme in Petroleum Geoscience with emphasis on Petroleum Geology and Petroleum Geophysics was introduced into UWI St Augustine Campus in September 2001. This was done at the request of the Geological Society of Trinidad and Tobago (GSTT), the Government, and the major upstream petroleum companies, all of whom assisted in the development (and continue to assist in the guidance) of this unique 3-year programme by forming an industry advisory committee (see Sub-sections 8.1 and 8.3).

The introduction of an undergraduate programme at UWI was a fast-track initiative. The complete 3-year programme was developed by the Engineering Faculty, with assistance from bpTT, and taken through all its committee stages within the St Augustine campus during May-July 2001. The UWI gave approval through the Board of Undergraduate Studies (housed at Mona, Jamaica) in mid July, and the programme was advertised in the Trinidad press on 12th August 2001. Over 50 applications were received by 21st August 2001, proving a demand for the programme from local people. Of the fifteen students accepted, fourteen had grade A in Advanced Level of mathematics, and six had scholarships from Government and Industry. Bringing on stream from conception in April 2001 to welcoming the first students in August 2001 is possibly a record for UWI!

Wayne Bertrand, an experienced petroleum geologist and at that time, Manager of the Business Development and Upstream Technical Services at Petrotrin, was seconded to the UWI part-time in August

2001 to provide leadership and programme coordination. This partnership ensured the programme's successful implementation. In 2008, after retirement from Petrotrin Mr. Bertrand joined the Faculty as Distinguished Fellow in Practice to continue the programme coordination.

Currently, most geoscientists worldwide come from Faculties of Science. The reason for having the programme in the Faculty of Engineering can be summed up by the following analogy, 'Petroleum geoscience is to geology as chemical engineering is to chemistry'. This Petroleum Geoscience undergraduate programme thus gives a very good grounding for Petroleum Engineering. It allows students to interact with engineers, appreciate the language, and more importantly, attain attitudes conducive to using applied sciences. It aids getting practicable solutions to problems, understanding numerical methods for risk, business and uncertainty and being familiar with engineering terms and practices for collaborative work.

The quantitative geoscience aims to provide the scientific knowledge to help find and develop hydrocarbon resources using geoscience and modern techniques, in particular for T&T and the Southeast Caribbean. The training consists of three years of study, each consisting of seven months of structured teaching and significant fieldwork, plus some 6-8 weeks of industry orientation and 10-12 weeks for an individual oilfield project usually in the industry, and some time for examinations. The curriculum and industry training is designed to produce well-rounded graduate geoscientists and engineers capable to fast track the upstream petroleum and gas industries that help find and develop petroleum resources both in T&T and the wider Caribbean (Dawe et al., 2007).

5. Current status of Petroleum Studies programmes:

5,1 Petroleum Engineering

In 2011, training in Petroleum Engineering at the UWI is provided through the MSc in Petroleum Engineering programme, a conversion course for students from other engineering and numerical science backgrounds and which has been the core of the teaching since 1991.

The MSc in Petroleum Engineering programme is a one-year full-time, or two-year part time, taught multidisciplinary programme of eight 4-credit courses, covering a wide range of earth science and related subjects and their application to the full spectrum of hydrocarbon exploration and production. The content of the programme is aimed at providing the necessary background for employment in the oil and gas industry, or springboard for a research degree, as well as serving as a refresher for those already working in industry.

The courses are completed in 2 full semesters, or 4 semesters part-time. This is followed by an individual research project worth 12 credits in total comprising a research methods portion (3 credits) and a project submission (9 credits). The programme is at present delivered in the evening (4 to 8 pm) with mainly part-time students and many of these graduates are already active in the upstream oil and gas industry in T&T. The MSc Petroleum Engineering programme is at present run with 4 full time and 1 part time members of staff. The Unit maintains close ties with the industry through the Joint Industry/ Academic Advisory Committee (see Sub-section 8.3), part-time lecturers from industry teaching on the programme and also through the Society of Petroleum Engineers (see Section 8.6) and, naturally, staff personal contacts.

The topics covered include reservoir mechanics, petroleum geoscience, production and process engineering, improved oil recovery, natural gas engineering, drilling engineering, pressure/volume/ temperature (pvt) and fluids, petrophysics, well test analysis, well completions, well logging and a group project, which is a complete development plan of a model field. It also covers some production economics, production logging and reservoir simulation. Students have field trips, petroleum engineering laboratories and, on occasions, seminars from industry.

The MSc programme in Petroleum Engineering is accredited by the Institute of Materials, Minerals and Mining and the Energy Institute (see Sub-section 8.6).

One of the requirements of the Master's programme is the completion of a Research Project where the student studies in some depth an aspect of petroleum engineering. The purpose is manifold including, helping the development of skills for a person to function more independently, and the opportunity to put classroom knowledge into practice. A Research Methods course has been introduced as a mandatory requirement of all graduate taught MSc programmes delivered at the UWI to try to help students complete their project. Within the Engineering Faculty it is in the form of a 3-credit course, where the development of the topic, initial programme methodology and literature review occurs. This is followed by the written individual research report.

Some students seem satisfied with the knowledge gained from the lectures and therefore do not place a high priority on the project, and so accept a Diploma, which the regulations now allow.

5.2 Petroleum Geoscience

The BSc in Petroleum Geoscience programme was designed to cover aspects of oil and gas winning, processing technology and hydrocarbon economics by providing both a theoretical and practical approach to petroleum geoscience problems and create an environment within which students can develop the technical expertise required to enter the hydrocarbon finding profession, or research in these fields. Over the decade 2001-2011, the programme has been gently modified to reflect industry current-practice and needs, but the emphasis still focuses on core geological disciplines significant for oil and gas exploration and

production. It then integrates this material and skills through an examination of industrial applications, with studies in oilfield development and computer analysis. This second phase includes more work on presentation skills, fieldwork and practical exercises that span such sub-disciplines as stratigraphy, basin analysis, geochemistry, and seismic interpretation, providing the opportunity for students to reinforce basic proficiencies and to use the latest industrial computer software. The syllabi and other teaching details are given in UWI's Faculty booklets (Faculty of Engineering, 2011).

The numbers, perhaps 15 in a programme, are programme-sustainable numbers, and allow good camaraderie between students. Also, this number can be absorbed by the industry, in the major companies or service companies, and in peripheral employment such as environmental agencies and academia. The syllabi and other teaching details are given in UWI's Faculty booklets (Faculty of Engineering, 2011).

Although the programme is aimed primarily at the oil industry, in predominately the Southeast Caribbean, and to be their main source of graduate professional petroleum geoscientists, the education provided offers the prospect of careers in other fields (such as water resource exploration, Health, Safety and Environment (HSE), and upstream technical Human Resources, etc). Thus, this unique programme is suitable to students from any (oil) country in the world

5.3 MPhil and PhD Degrees

These degrees are awarded after completion of in-depth research programmes usually in-house and with minimum times of 2 and 3 years, respectively. Topics normally follow the specific Academic staff or student interests but with direct inputs from the industry. Up to now, these programmes have never really been popular within the oil industry, because industry itself conducts its own advanced studies for immediate practical applications, but nevertheless they can provide valuable specialist training.

5.4 Postgraduate Diploma in Petroleum Engineering

The Petroleum Engineering Unit wishes all students to have some reward for passing their courses. However, a significant number of MSc candidates do not complete their individual project, and so would leave UWI with no credit for what they have achieved (i.e. passed examinations). It was therefore requested in 2004 that the UWI Board for Graduate Studies and Research allow a Postgraduate Diploma in Petroleum Engineering to be awarded if the candidate passes six examination courses. Some individual project work is included in some of the courses, but there is no formal project course to complete. The standards of examination etc. are identical to the MSc, but this is a way to recognise, reward and bring to completion the success in having passed these courses. In total, some 82 students have taken up this route for throughput and success; the Diploma is, however, not a CEng accredited route, and students are so advised.

6. Some Student Statistics

To date, some 429 students have graduated from the various Petroleum Studies programmes. Table 1 shows the statistics: 144 MScs, 104 Diplomas, 113 BSc Petroleum Geoscience, 48 BSc Petroleum Engineering, 17 MPhil and 3 PhDs. Some 65 MSc, 41 undergraduate and 2 PhD students are currently registered.

The academic quality of the students registered for the Petroleum Engineering graduate programmes is such that most have 1st or 2nd upper class honours and at least one year away from University. Also, most are already employed in the petroleum industry with strong support from their employer. This suggests that the programme is helpful and/or necessary to their job. The enrolment onto the programme is approximately 20-25 per year of the 50-70 applicants, mainly part-time but a sprinkling of full-time.

The programme enables the student to develop from the essential basics, leading to more advanced reservoir engineering topics through practical aspects of drilling and production to the final supervised group project, where the group works as a unit with guidance, and then to independent study by undertaking their research project.

There are various reasons for a student leaving the system voluntarily. Typically, the reasons are work related, usually promotion, new job or assignment overseas, although a more recent one has been withdrawal due to pressure of job-work. Many students starting work at 7 am and as classes are 4-8 pm, some students become physically exhausted because of traffic congestion adding to the travel times.

The progress of the Petroleum Geoscience programme since inception in 2001 has been phenomenal. It has produced in Trinidad, initially for the T&T petroleum industry, a small number (i.e., 10-17 per annum) of exceptionally well-educated Petroleum Geoscientists, competent and confident with the aspects of geological and geophysical science needed for fast-track employment for hydrocarbon exploration and production, particularly computer applications. The programme has become the industry's main source of young graduate professional Petroleum Geoscientists in Trinidad, and is viable at 8-15 students per year for, at least, the near future. So far by 2011, 113 students have graduated. Some graduates have been posted abroad by their companies for career development; others (>25) have already gained a Masters degree abroad (8 with distinction), or are currently abroad for further study (8 for PhD studies in reputable universities), often sponsored by a company or the Government.

Table 1. Student Graduating Statistics of the Petroleum Studies Programmes at the UWI

Programme	Dates	No of Graduates	Comments
Taught Masters			
MSc Petroleum Engineering	1981-	Current total: 117 (by 2000, 40) (by 1996, 25)	Has changed its courses over the years. In 2010, a Research Methods was course introduced to help students gain confidence in getting project started.
MSc Petroleum Engineering and Management	1986 – 1992	12	Discontinued due to poor support.
MSc Petroleum Management	1986 – 1992	15	Discontinued due to poor support.
Undergraduate			
BSc Petroleum Engineering	1977 - 1986	48	Discontinued in 1989 due to poor student numbers (Classification and number of degrees awarded*; 1- 4; 2U –18; 2L–22; 3- 0; Pass- 4)
BSc Petroleum Geoscience	2001-	113 (by 2011)	Classification and number of degrees awarded*; 1-46; 2U-58; 2L-8; 3-1
Diploma			
Diploma in Petroleum Engineering, with project	1976-1979 reintroduced 1986 - 1989	22 (by 1996)	Discontinued due to poor support
Diploma in Petroleum Engineering, without project	2004 -	82 (by 2011)	Introduced to help those who could not finish the MSc, but had passed at least 6 courses.
Higher degree			
MPhil in Petroleum Engineering (or Geoscience)	1979 -	17	15 by 1996, 1 in 2009, 1 in 2011
PhD in Petroleum Engineering	1979 -	3	1982, 1993, 2004
Total:		429	Some 22 graduates have more than one degree in Petroleum Studies.

*Remarks: 1 – First Honours; 2U – Second Upper; 2L- Second Lower; 3 – Third; Pass – Pass Degree

7. Research

Research initiatives are concentrated on the needs of the T&T hydrocarbon producing industry. Contacts with the major industry players are identifying the best and most useful directions.

All MSc students have to carry out a Research Project after completion of all the teaching courses to fulfil the requirements for the award of the degree. Since most students are employed in the industry by the time they have completed the taught courses, it is appropriate for the students to choose projects associated with their workplace. This means that they can carry out their projects with minimum competition for the student's time from his/her employer. In addition, it also means that the results obtained will normally be of direct benefit to the company in improving their operations.

Even so, much of the areas of research projects have tended to follow specialty areas of the lecturers in the Unit, production, reservoir engineering, drilling and enhanced oil recovery and various aspects of petroleum economics and management. Thus topics that have been pursued during the period 1980-2000 were gas lift, sucker rod pumping, steam flooding, phase behaviour, reservoir modelling, and carbon dioxide flooding. Research in the field of Enhanced Oil Recovery, primarily on thermal recovery methods, was started through a joint effort with the National Institute for Higher Education, Research, Science and Technology (NIHERST). The main topics covered the characterisation of Trinidad crudes (including phase behaviour), use of steam in enhanced oil recovery, miscible and immiscible carbon dioxide studies as well as in-situ combustion. However, the turnover of staff affected any continuity. Since 2000, specialty areas include production, reservoir engineering, drilling and enhanced oil recovery, especially heavy oil, and sand control which is important for Trinidad production.

A PVT Laboratory was developed for anticipated work of oil and gas analysis for the companies especially due to industry thermal projects coming on stream, but due to the low oil price in the late 1980's, the plans were curtailed, so the laboratory never became commercial. Some black oil studies were carried out for Trintoc, Amoco, but the Laboratory became inoperational due to difficulties with spares, maintenance and technical ability. However some personnel were trained.

Since 1999 after Professor Dawe took the TTMC Chair in Petroleum Engineering, major petroleum research interests moved to topics in the areas of reservoir engineering and petroleum geoscience, particularly visualising reservoir behaviour and reservoir physical properties. The question 'How does an oil reservoir work?' was being answered. Topics included fundamentals of enhancing oil recovery, especially heavy oil, the physical properties of petroleum fluids, hydrocarbon phase behaviour, retrograde condensate and solution gas drive physics in porous media. Recently heavy oil recovery including the new vapour extraction (VAPEX) process (Roopa and Dawe, 2007), particularly the required understanding of the phase behaviour, has

been pursued. Another interest has been natural gas hydrates (NGH), particularly for gas transport and future energy resources. Current topics include:

- Heavy oil - vapour extraction via horizontal wells; downhole heating; foamy oil; heavy oil wastewater cleanup; asphaltene production problems.
- Hydrates - transporting stranded natural gas around the Caribbean using gas hydrates (GtS); desalination by gas hydrates; unconventional source for gas from sub-sea hydrates.
- Gas condensates - Production performance of gas condensate reservoirs; Equation of State (EOS) modelling of phase behaviour of gas condensates.
- Sand - monitoring in production pipelines.
- Heterogeneity effects (permeability and wettability) on reservoir flow and displacement.
- Gas lift.
- Pore pressure prediction models.
- Pressure drop analysis in high rate large internal diameter completion assemblies.
- Optimisation of the depletion of thin oil rims.
- Producing characteristics of gas reservoirs.
- Multiphase flow correlations for gas wells.
- Environment considerations - zero pollution, oil-water separation, gas flotation of oily wastewaters, biotechnolgical inputs.

The findings since 1999 have been presented in some 100 papers.

Geoscience research has also centred on the interests of lecturers but, given the strong industrial leanings in the programme, has produced results useful in hydrocarbon exploration. Research themes include sedimentology and micropalaeontology, but both subject areas have been integrated to enhance knowledge of the geological evolution of T&T and the adjacent SE Caribbean Sea. Some research has included input from summer interns - especially those just finishing their first year as undergraduates.

8. Alliances with Local Industry

8.1 Industry contributions

The strongest feature of the Petroleum Studies programmes at the UWI is the fact that Trinidad is an oil production and processing country and the industry is actively participating in the programme. Most members of staff have work experience in the field and all staff have strong links with both industry and government. Industry provides financial support for some academic posts, equipment, bursaries and scholarships. Visiting lecturers from industry and government establishments contribute significantly to the more specialised courses. An industry-based steering committee, the JIAAC (discussed below), formed by stakeholders, plays a crucial role in continuing the development of the programmes, because it helps align the programmes and course work to industry needs.

8.2 Employment

Over the years, often when large producing companies are hiring there are shortages and with bulk (panic) hiring, some of their hirees are not fully qualified, but then when they are later 'right sizing' their staff numbers, often their staff sizes are rapidly reduced, without thought for the long-term future, so there is expertise loss. Succession planning has not been practiced. At these times, small producing companies and service companies grow because the majors contract work to them. Additionally, over the last four decades, there has been a steady loss of critical skills from the industry, usually with the older experienced personnel leaving before their skills have been properly 'handed down'.

The majority of the 429 who have graduated from the programmes - MSc, BSc, Diploma, MPhil and PhD - are active in the upstream oil and gas industry in T&T. In fact, the Unit provides the majority of the locally trained professionals therein. Many upon graduation have found employment in the upstream petroleum sector with major oil companies, service companies or the Ministry of Energy and Energy Affairs (MoEEA).

8.3 JIAAC

The Unit cannot satisfactorily achieve relevant teaching without close relationships with the industry. A Joint Industry/Academic Advisory Committee (JIAAC), with representatives from the major petroleum players in T&T, meets every semester to give input into the programme. This essential partnership enables the programme to maintain relevance, focus, and up-to-date direction. The terms of reference of the JIAAC are to advise on:

- the development and maintenance of adequate contact and collaboration between the Faculty of Engineering and Industry in the general field of petroleum exploration and exploitation engineering
- the education and training of petroleum geoscientists and engineers
- the development of arrangements with industry to ensure a flow of sponsored students and support for faculty and research.

The JIAAC is particularly helpful in obtaining industry scholarships and other funds, work placements, and project ideas. Additionally, there is the opportunity to discuss recruitment patterns, manpower strategic planning within the industry, and trends in 'company needs' that can be included in the programmes. Clearly, the academic responsibility is with the University, but the dialogue is important.

Funding has been generously donated to the Petroleum Geoscience programme by the major players in Trinidad, such as bpTT, BG-TT, EOG Resources, NGC, Petrotrin, Schlumberger, CL Financial, the Ministry of Energy and Energy Industries (now, Affairs),

and the BHP consortium (BHP, Talisman, Total-Fina-Elf and BG). The major oil companies are therefore fully involved, including mentoring Petroleum Geoscience students' projects in their final year. bpTT in particular have been very generous to the programmes with scholarships, substantial bursaries to ensure the smooth running of the programme support for a lecturer, for research, external examiner's visit and for fieldwork.

8.4 Internships Industry contact: The Petroleum Geoscience Programme

In the long vacation at the end of the second year, students have a three-month internship with industry, continued throughout their final year (i.e., year 3). Students work at the company premises, gaining hands-on experience and industry attitudes to work ethics, while an industry mentor closely supervises their work. The results of this work are submitted as a project dissertation. During the long vacation between years 1 and 2, most Petroleum Geoscience students undertake an eight-week internship in industry. However, there is much competition for limited places. Students mature greatly during this period, both technically and personally.

8.5 Professional Development, Chartership and Accreditation

Throughout the engineering profession worldwide, there is a move to ensure that all professional engineers and geoscientists keep their skills up to date. This requirement is met mainly by short courses for Continual Professional Development (CPD). There are also a number of routes to become a professional or Chartered Engineer to ensure that professional standards and ethics are established and maintained. In a number of countries (e.g. the USA, Canada, and the UK), there is a professional register of engineers and geoscientists and a number of bodies affiliated to this register, and provide various routes for people to become registered. To become registered there are a number of requirements, including proper training and proper experience. The training is usually in the form of the degree that a person has obtained. For professional Petroleum Engineers and Geoscientists in T&T, there may be legislation soon to demand that various legal documents need to be signed-off by a registered professional engineer.

Four-year programmes have been discussed within the Faculty of Engineering, particularly their effect on accreditation through the Engineering Council. The Faculty has 3-year BSc engineering programmes followed by a Further Learning (MSc) programme to gain the 4-year training needed for CEng chartership. Graduates from the undergraduate Petroleum Geoscience programme, who are well trained for the MSc in Petroleum Engineering programme can go on to undertake our MSc in Petroleum Engineering, or externally elsewhere, as indeed many have done.

The Petroleum Engineering MSc at the UWI has been accredited by the Institute of Materials, Minerals and Mining (IOM^3) in 2006 and the Energy Institute (EI) in 2010, thus students have their educational needs toward Chartered Engineer status satisfied. As a result, graduates are able to go forward for Chartering by IOM^3 or EI after 4-6 years suitable professional experience and responsibility. Similarly, the educational needs of the Petroleum Geoscience graduate have been covered by the Geological Society of London which has re-accredited the programme until 2016 and the Energy Institute till 2013. This is the first undergraduate Petroleum Geoscience programme accredited outside the UK.

8.6 Professional Societies

The Petroleum Studies Unit has strong links with the local chapters of the Society of Petroleum Engineers, (SPE), the Geological Society of Trinidad and Tobago (GSTT), the Formation and Evaluation Society of Trinidad and Tobago (FESTT), the American Association of Petroleum Geologists (AAPG), the Energy Institute and the Society of Exploration Geophysicists (SEG). The aim of all these professional international learned groups is to disseminate frontier knowledge from fundamental to field experience.

Over the years, each society has been most generous in its support to the Petroleum Studies Unit at the UWI, including welcoming students to their meetings and conferences, scholarship support, and giving donations to the library and student membership either free or for a small fee. Various lunch time or evening or one-day meetings take place within Trinidad, and if relevant, the staff members do their best to modify timetables to accommodate these meetings.

The SPE and AAPG have excellent technical paper libraries and the UWI library currently subscribes to the publications from these societies. The SPE is an international learned society looking after Petroleum Engineering. The aim of the SPE is to disseminate frontier knowledge spanning the fundamental sciences to field applications. Over the years, the local chapter of SPE has been most generous in its support to Petroleum Engineering at UWI, including scholarship support, running a student paper contest, welcoming students to their meetings and conferences, and giving donations to the library.

9 Staffing and External Examiners

The Petroleum Engineering programme was established with eight Academic posts, but the oil crisis of the late 1980's created a crisis within the Unit. With the decline in students entering the BSc programme, the number of staff dedicated to the teaching of Petroleum Engineering soon dwindled from the original eight to four and then to only one full-time member in 1998. In 2011, there are four full-time Petroleum Engineering academic staff.

Programme leader Petroleum Engineering, Richard Dawe and three lecturing staff, Clyde Abder, Raffie Hosein, and Jill Marcelle-de Silva (see Figure 2)

Figure 2. The Petroleum Engineering teaching staff, 2011 (*Top*: C. Abder, R. Hosein, and W. Bertrand *Sitting*: R.A. Dawe and J. Marcelle-De Silva)

The Petroleum Geoscience programme, started in 2001, is now in its tenth year, has as its main core five dedicated full-time teaching staff, giving a student/permanent staff ratio of around 10:1. The programme is led by Wayne Bertrand and supplemented by expertise of some fifteen (15) part-time specialists who are involved in delivering the programmes. The part-time lecturers from industry have been used effectively for teaching. However, this had a serious impact on the ability of the Unit to carry out and encourage research, reflected in the fact that only three Doctorates have been awarded so far.

The primary functions of external examiners are to ensure the academic standards are maintained, and that the Unit is being fair to all students. To achieve this, the external examiner, following current Faculty of Engineering practice, has to approve all examination questions, and independently assesses a selection of examination scripts, projects and other coursework items.

10. Impact and People

The UWI as an institution has contributed tremendously to the Caribbean Region. The majority of the current leaders, political and Industrial have some association with the UWI, either as an undergraduate or advanced degree.

The Petroleum Studies Unit has itself contributed, significantly to the development of the Petroleum Industry in Trinidad. As stated, 429 students have graduated from the various Petroleum Studies programmes. Some 90 students are currently registered (including 40 undergraduates and 50 graduates), plus a number with their projects to finish. Most of these graduates and students are active in the upstream Petroleum Industry in T&T, and the Unit has provided the majority of the local trained professionals therein.

The Unit has as its alumni a wide variety of 'successes' including two Ministers of Energy, a Permanent Secretary, CEOs and leading Petroleum Engineers. The SPE Trinidad Section has had at least eight alumni as chairman, and many others have been members of the committee. The 3 PhDs have all been on the academic staff for a while. The percentage of local Petroleum Engineers in the industry has increased from approximately 10% in the early 1970's to 85% some 45 years later in 2011. This small summary neglects the many others (more than 300) that are active, many within the industry worldwide, but gives a flavour of the significant impact that the Petroleum Studies Unit at the UWI has had on the local industry, in terms of its formal training programmes.

11. Conclusions

In conclusion, the Petroleum Studies programmes fill an important need by educating local professionals for employment in the industry. The impact of petroleum studies unit within the Caribbean, and T&T in particular, has been significant. The percentage of local Petroleum Engineers in the industry has increased from approximately 10% in the early 1970's to 85% in 2011. This demonstrates that the Petroleum Studies Unit at the UWI is highly relevant to the local industry in terms of its formal training programmes.

An infusion of new able recruits into the upstream petroleum profession is an important recruitment challenge. The Petroleum Studies Unit at the UWI believes that, by working in conjunction with the industry it serves, it is achieving this.

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Authors' Biographical Notes:

Richard A. Dawe *was the first holder of the TTMC (Trinidad and Tobago Methanol Company) Chair in Petroleum Engineering in the Department of Chemical Engineering. He joined UWI in August 1999. Professor Dawe was Head of the Petroleum Studies Unit 1999-2011. Richard Dawe holds a MA and DPhil in Physical Chemistry from the University of Oxford (1968), and has followed an academic career with research interests in the broad area of petroleum engineering/geoscience and applied thermodynamics. He had taken early retirement from Imperial College, the UK in September 1997, after being in post there for 22 years, and had risen to become the Reader in Reservoir Physics in the Department of Earth Resources Engineering. In his career, Professor Dawe has published over 230 papers mainly on his research interests and edited the book 'Modern Petroleum Technology' (2000) with chapter contributions. In 2005, he was selected for the Vice-Chancellor's Award. Emeritus Professor Dawe retired from UWI in July 2011.*

Raffie Hosein *is currently a Senior Lecturer in the Petroleum Studies Unit at The University of The West Indies in Trinidad. Previously he worked as a Petroleum Engineer with the Ministry of Energy in Trinidad (September 2000-June 2006) and then as a Senior Associate Professor in the Department of Petroleum Engineering at Texas A&M University at Qatar (July 2006-July 2009). He received his B.Sc., M.Phil. and Ph.D degrees in Petroleum Engineering from The University of The West Indies in Trinidad. His area of specialty and teaching consultation (NExT) is in phase behaviour of reservoir fluids and PVT. His technical publications are on reservoir fluid characterisations, Equation of State Predictions, Carbon Dioxide Sequestration and on Trinidad heavy Oil. His current area of research is in the recovery of Trinidad heavy oil.*

Jill Marcelle-De Silva *is currently a lecturer in the Petroleum Studies Unit at The University of The West Indies in Trinidad. She is a petroleum engineer by profession with 17 years experience in the energy sector at Petrotrin (Trinidad) and later as a Senior Reservoir Engineer at BP Trinidad and Tobago LLC. She holds both B.Sc. and M.Sc. Degrees in Petroleum Engineering from the University of the West Indies (UWI), and an Engineer's Degree in Petroleum Engineering from Stanford University, California. Her professional career involved experience in numerical simulation, risk analysis, enhanced oil recovery, estimation of oil and gas reserves, and optimising the production performance of oil and gas fields. She joined the Petroleum Engineering Unit UWI in 2000, and has published technical papers on natural gas hydrates, development of thin oil rims and major gas fields, and the effects of permeability and wettability heterogeneities on flow in porous media. Her current area of research is the characterisation of potential hydrate bearing sediments offshore Trinidad and Tobago.*

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