封面格式

行政院及所屬各機關出國報告

（出國類別：　研究　　）

油層工程整合性應用研究

服務機關：中國石油股份有限公司
台灣油礦探勘總處
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出國地區：美國
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一、前言

八十八年下半年及八十九年度國外專題研究〝油層工程整合性應用研究〞項下，經提研習計劃(如附錄)赴美國德州 IS 公司及 Corlena公司研習，安排住宿於出租公寓，一房一廳(one bed room)月租為 1200 元，周日上班由 IS 公司提供便車，赴油田參訪或假日外出則租車前往，雖經費襟拙，唯尚有薪金支應，平日簡單的生活習慣，也可愉快享受進修生活，美國生活昂貴，生活上感覺新台幣之價值被低估了。

達拉斯係美國石油工程學會 SPE 之所在地，石油工程之圖書文獻十分豐富就近利用獲益不少。

IS 公司提供電腦設備與網路資源，及其投資油氣田之資料。

德州東部 Kilgore 係德州石油案之發祥地，現已枯竭市況大不如前，有一石油博物館展示其先民發展油礦事業之簡陋而實際。

北德州與奧克拉荷馬州一帶油田到處可見，奧州政府辦公室前還有油田遺址，適逢油價起漲，石油雜誌散見徵求停產油氣井買入之小廣告，充分說明油價高低與生產之關係。

二、對油層工程一些心得

油層工程最重要之任務之一為確保蘊藏量估計的實現性，依 SPE 之定義(最新版 SPE 出版之定義如附錄)，簡言之，可用合乎經濟之方法採得之石油才能稱為 Reserve，最常用體積法之估算蘊藏量：

Reserve＝A、h、ϕ、S_o、B_o、R………

A：面積，在未再開發前完全依賴地質、地球物理的方法解釋之，工程資料漸增後可回饋地質參數，反覆處理修正提高準確度。

h：厚度，與面積參數同性質，在未開發前亦依賴地質、地球物理的方法及待鑽採後實際資料與解釋資料可取後較佳之相關資料，對厚度參數可有較佳之掌握。

ϕ：孔隙率，未鑽探前僅能依地質地物資料類比估計，鑽探後

電測及岩屑岩心的資料可獲較佳之估算，惟與量測方法的不同尚有顯著的差異，且空間上的採樣還是要資深地質師的判斷才能彌補管窺之憾，及至有流體溫壓及量之資料後或可有較佳之推論。

So：與ϕ之性質類似，生產過程與不同流體間之相對變化數學上敏感，由實驗室精確之量測顯得很重要。

Bo：體積因素，以油氣樣本於實際室中分析而得，採樣方法與技術之良窳影響很大。

R：採收率，採收率為地層特性，開發規劃、生產管理、市場狀況………等因素之綜合表現歷史經驗值從 5%到 40%均有之，並因二、三期採收的規劃與技術改進有很大的關係，油層技術與管理均展現與此。

上述六個參數外，尚可加入其他的因子，例如加入體積因子，即將體積之估計再打一折扣，例如也有人加入地層連續性因子也是將體積打一折扣，打折就是保守之意，但過於保守也無法成就任一事業，因於不準度如此之高，遂有機率法應運而生。油層工程最重要的參數滲透率，不含於體積法之計算中，其實係隱含於採收率之中，其中之變化很容易被簡單的假設所掩蓋，因而使前期探勘之努力毀損。再透過油層模擬，對未來生產情境做合理的預測，以與地層資料核對，合理微調參數，若不能得合理預測，則各領域專業對個自之研判，應有自省之反應，相互回饋，才有績效。個人的專業實在非常渺小，難能獨斷，團隊互補實為成功關鍵。

三、進修計劃的實行

IS 公司係一探勘公司總裁本身之專業為地球物理解釋，從事停產油田之再評估，再投資及小氣田之買賣。由改變 data Processing 之程序，改變參數後之再處理，實際工作上以德州 Panhandle 地區 Walker County 的 Dalhart 油田，在 Granite Wash 地層，決定在 2175 呎深度往 45° bearing 鑽水平井，水平段 200

呎由 Corlena 公司執行，鑽井預算約 22 萬美元，預計可獲日產 100 桶，有利可圖，簡要資料如附錄。再者為了油層模擬，市面上油層模擬軟體很多，也是高價格，要向顧問公司借用也須付費使用，對進修者而言，實在不方便。美國能源部在奧克拉荷馬州土剎市有一〝National Petroleum Technology Office〞可提供免費軟體，我透過網路獲贈乙套，爾後油層評估上有所助益，其行政效率之快，令人印象深刻。

進修期獲邀往訪加拿大莎斯卡其旺省研究院石油研究所(Petroleum Division, Saskatchewan Research Council)各位老友相見歡，傾聽其研究概況，包括水平井技術、甲烷循環注氣重油採收，注入空氣油層現地燃燒(火攻)採收法，注二氧化碳排掃中輕質油採收，乳化輸送研究，重油升級研究，參觀了其實驗設備，並在南莎省參訪油氣田，重溫學習旅程快樂時光(如附錄)。該所獲加國聯邦政府及石油業大量基金之援助，研究大樓遷建於女王大學之校區中，顯見採收技術之研究仍可獲得社會之支持，很為研究人員慶幸，只要能為工業界促進發展研究業之前途還是光明的。

SRC 對石油整合研究也很重視，常找專家來開 Seminar，主要講題如 Reservoir Management Concepts， Reservoir Management Process, Data Acquisition, Analysis Management, Reservoir Performance Analysis and Forecast, Reservoir Management Economics, Improved Recovery Process， Reservoir Management Case Studies。印象深刻，蒐集一些書目(如附錄)，可供日後自修參考用。

四、結語與建議

過去 30 年來油層工程在整合上有十足的進步，技術與工具均有進步，油層特性描述方法也有改進，個人電腦及自動化的普及提昇資料處理與管理能力。地質與工程專業之互動，促成新團隊的成功。油層工程整合觀念也在石油業界中被接受，由原先

接力團隊漸變成職籃團隊。

整合方法的實踐配以新科技，吾人相信所有油氣田的採收率會提昇，使全球性石油耗竭時間往後延伸，是全球的共同利益。

油層工程的整合，從設定目標、計劃、動工、監管、再評估及計劃再修訂，生生不息。

感謝公司給我機會，進修期間竭盡利用時間多聽、多看，對爾後工作品質之提昇必有所助益。此種計劃經費不多，爾後可以繼續辦理。

沈士傑赴美國德州 IS 公司及 Corlena Oil 研習
〝油層工程整合性研究〞計劃

藉由實際參與 IS 公司及其投資於 Corlena Oil 公司在美國德州 Granite Wash 油層的復產計劃，研習油層工程師對於油田的實際經營上，所應扮演的角色。除了可以瞭解專營探勘與生產之油公司的經營理念及業界之做法外，技術上包括：

一、未排掃油田之發現方法與解釋

(一)Development G & G

1.reservoir characterization

2.reservoir heterogeneity and discontinuity

(二)Pressure Transient Testing

1.field case study

2.mesurement method

(三)Formation Evaluation

1.oil-in-place determination for EOR

2.reservior description

(四)Reservoir Engineering

1.reservoir simulation field studies

2.technique of reserve and oil-in-place determination

二、油田復產計劃的實施

(一)Artificial lift Technology and equipment

(二)Design and operation of field

(三)Production and injection system

(四)Measurement

三、油層管理

(一)Depletion plan

(二)Business planning and strategies

PETROLEUM RESERVES DEFINITIONS

SOCIETY OF PETROLEUM ENGINEERS (SPE) AND WORLD PETROLEUM CONGRESSES (WPC)

PREAMBLE

Petroleum[1] is the world's major source of energy and is a key factor in the continued development of world economies. It is essential for future planning that governments and industry have a clear assessment of the quantities of petroleum available for production and quantities which are anticipated to become available within a practical time frame through additional field development, technological advances, or exploration. To achieve such an assessment, it is imperative that the industry adopt a consistent nomenclature for assessing the current and future quantities of petroleum expected to be recovered from naturally occurring underground accumulations. Such quantities are defined as reserves, and their assessment is of considerable importance to governments, international agencies, economists, bankers, and the international energy industry.

The terminology used in classifying petroleum substances and the various categories of reserves have been the subject of much study and discussion for many years. Attempts to standardize reserves terminology began in the mid 1930's when the American Petroleum Institute considered classification for petroleum and definitions of various reserves categories. Since then, the evolution of technology has yielded more precise engineering methods to determine reserves and has intensified the need for an improved nomenclature to achieve consistency among professionals working with reserves terminology. Working entirely separately, the Society of Petroleum Engineers (SPE) and the World Petroleum Congresses (WPC) produced strikingly similar sets of petroleum reserve definitions for known accumulations which were introduced in early 1987. These have become the preferred standards for reserves classification across the industry. Soon after, it became apparent to both organizations that these could be combined into a single set of definitions which could be used by the industry worldwide. Contacts between representatives of the two organizations started in 1987, shortly after the publication of the initial sets of definitions. During the World Petroleum Congress in June 1994, it was recognized that while any revisions to the current definitions would require the approval of the respective Boards of Directors, the effort to establish a worldwide nomenclature should be increased. A common nomenclature would present an enhanced opportunity for acceptance and would signify a common and unique stance on an essential technical and professional issue facing the international petroleum industry.

As a first step in the process, the organizations issued a joint statement which presented a broad set of principles on which reserves estimations and definitions should be based. A task force was established by the Boards of SPE and WPC to develop a common set of definitions based on this statement of principles. The followin joint statement of principles was published in the January 1996 issu of the SPE *Journal of Petroleum Technology* and in the June 199 issue of the *WPC Newsletter*:

> *There is a growing awareness worldwide of the need for consistent set of reserves definitions for use by governments an industry in the classification of petroleum reserves. Since the introduction in 1987, the Society of Petroleum Engineers and th World Petroleum Congresses reserves definitions have bee standards for reserves classification and evaluation worldwide.*
>
> *SPE and WPC have begun efforts toward achieving consistency i the classification of reserves. As a first step in this process, SP and WPC issue the following joint statement of principles.*
>
> > *The SPE and the WPC recognize that both organization have developed a widely accepted and simple nomenclatur of petroleum reserves.*
> >
> > *The SPE and the WPC emphasize that the definitions a intended as standard, general guidelines for petroleu reserves classification which should allow for the prop comparison of quantities on a worldwide basis.*
> >
> > *The SPE and the WPC emphasize that, although the defin tion of petroleum reserves should not in any manner b construed to be compulsory or obligatory, countries an organizations should be encouraged to use the core defin tions as defined in these principles and also to expand o these definitions according to special local conditions an circumstances.*
> >
> > *The SPE and the WPC recognize that suitable mathemati techniques can be used as required and that it is left to th country to fix the exact criteria for reasonable certainty existence of petroleum reserves. No methods of calculatio are excluded, however, if probabilistic methods are used, th chosen percentages should be unequivocally stated.*
> >
> > *The SPE and the WPC agree that the petroleum nomencla ture as proposed applies only to known discovered hydroca bon accumulations and their associated potential deposits*
> >
> > *The SPE and the WPC stress that petroleum proved reserve should be based on current economic conditions, includin all factors affecting the viability of the projects. The SPE an the WPC recognize that the term is general and not re stricted to costs and price only. Probable and possibl reserves could be based on anticipated developments and/o the extrapolation of current economic conditions.*
> >
> > *The SPE and the WPC accept that petroleum reserv definitions are not static and will evolve*

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[1] **PETROLEUM:** For the purpose of these definitions, the term petroleum refers to naturally occurring liquids and gases which are predominately comprised of hydrocarbon compounds. Petroleum may also contain non-hydrocarbon compounds in which sulfur, oxygen, and/or nitrogen atoms are combined with carbon and hydrogen. Common examples of non-hydrocarbons found in petroleum are nitrogen, carbon dioxide, and hydrogen sulfide

A conscious effort was made to keep the recommended terminology as close to current common usage as possible in order to minimize the impact of previously reported quantities and changes required to bring about wide acceptance. The proposed terminology is not intended as a precise system of definitions and evaluation procedures to satisfy all situations. Due to the many forms of occurrence of petroleum, the wide range of characteristics, the uncertainty associated with the geological environment, and the constant evolution of evaluation technologies, a precise classification system is not practical. Furthermore, the complexity required for a precise system would detract from its understanding by those involved in petroleum matters. As a result, the recommended definitions do not represent a major change from the current SPE and WPC definitions which have become the standards across the industry. It is hoped that the recommended terminology will integrate the two sets of definitions and achieve better consistency in reserves data across the international industry.

Reserves derived under these definitions rely on the integrity, skill, and judgment of the evaluator and are affected by the geological complexity, stage of development, degree of depletion of the reservoirs, and amount of available data. Use of these definitions should sharpen the distinction between the various classifications and provide more consistent reserves reporting.

DEFINITIONS

Reserves are those quantities of petroleum which are anticipated to be commercially recovered from known accumulations from a given date forward. All reserve estimates involve some degree of uncertainty. The uncertainty depends chiefly on the amount of reliable geologic and engineering data available at the time of the estimate and the interpretation of these data. The relative degree of uncertainty may be conveyed by placing reserves into one of two principal classifications, either proved or unproved. Unproved reserves are less certain to be recovered than proved reserves and may be further sub-classified as probable and possible reserves to denote progressively increasing uncertainty in their recoverability.

The intent of the SPE and WPC in approving additional classifications beyond proved reserves is to facilitate consistency among professionals using such terms. In presenting these definitions, neither organization is recommending public disclosure of reserves classified as unproved. Public disclosure of the quantities classified as unproved reserves is left to the discretion of the countries or companies involved.

Estimation of reserves is done under conditions of uncertainty. The method of estimation is called deterministic if a single best estimate of reserves is made based on known geological, engineering, and economic data. The method of estimation is called probabilistic when the known geological, engineering, and economic data are used to generate a range of estimates and their associated probabilities. Identifying reserves as proved, probable, and possible has been the most frequent classification method and gives an indication of the probability of recovery. Because of potential differences in uncertainty, caution should be exercised when aggregating reserves of different classifications.

Reserves estimates will generally be revised as additional geologic or engineering data becomes available or as economic conditions change. Reserves do not include quantities of petroleum being held in inventory, and may be reduced for usage or processing losses if required for financial reporting.

Reserves may be attributed to either natural energy or improved recovery methods. Improved recovery methods include all methods for supplementing natural energy or altering natural forces in the reservoir to increase ultimate recovery. Examples of such methods are pressure maintenance, cycling, waterflooding, thermal methods, chemical flooding, and the use of miscible and immiscible displacement fluids. Other improved recovery methods may be developed in the future as petroleum technology continues to evolve.

PROVED RESERVES

Proved reserves are those quantities of petroleum which, by analysis of geological and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under current economic conditions, operating methods, and government regulations. Proved reserves can be categorized as developed or undeveloped.

If deterministic methods are used, the term reasonable certainty is intended to express a high degree of confidence that the quantities will be recovered. If probabilistic methods are used, there should be at least a 90% probability that the quantities actually recovered will equal or exceed the estimate.

Establishment of current economic conditions should include relevant historical petroleum prices and associated costs and may involve an averaging period that is consistent with the purpose of the reserve estimate, appropriate contract obligations, corporate procedures, and government regulations involved in reporting these reserves.

In general, reserves are considered proved if the commercial producibility of the reservoir is supported by actual production or formation tests. In this context, the term proved refers to the actual quantities of petroleum reserves and not just the productivity of the well or reservoir. In certain cases, proved reserves may be assigned on the basis of well logs and/or core analysis that indicate the subject reservoir is hydrocarbon bearing and is analogous to reservoirs in the same area that are producing or have demonstrated the ability to produce on formation tests.

The area of the reservoir considered as proved includes (1) the area delineated by drilling and defined by fluid contacts, if any, and (2) the undrilled portions of the reservoir that can reasonably be judged as commercially productive on the basis of available geological and engineering data. In the absence of data on fluid contacts, the lowest known occurrence of hydrocarbons controls the proved limit unless otherwise indicated by definitive geological, engineering or performance data.

Reserves may be classified as proved if facilities to process and transport those reserves to market are operational at the time of the estimate or there is a reasonable expectation that such facilities will be installed. Reserves in undeveloped locations may be classified as proved undeveloped provided (1) the locations are direct offsets to wells that have indicated commercial production in the objective formation, (2) it is reasonably certain such locations are within the known proved productive limits of the objective formation, (3) the locations conform to existing well spacing regulations where applicable, and (4) it is reasonably certain the locations will be developed. Reserves from other locations are categorized as proved undeveloped only where interpretations of geological and engineering data from wells indicate with reasonable certainty that the objective formation is laterally continuous and contains commercially recoverable petroleum at locations beyond direct offsets.

Reserves which are to be produced through the application of established improved recovery methods are included in the proved classification when (1) successful testing by a pilot project or favorable response of an installed program in the same or an analogous reservoir with similar rock and fluid properties provides support for the analysis on which the project was based, and, (2) it is reasonably certain that the project will proceed. Reserves to be recovered by improved recovery methods that have yet to be established through commercially successful applications are included in the proved classification only (1) after a favorable production response from the subject reservoir from either (a) a representative pilot or (b) an installed program where the response provides support for the analysis on which the project is based and (2) it is reasonably certain the project will proceed.

UNPROVED RESERVES

Unproved reserves are based on geologic and/or engineering data similar to that used in estimates of proved reserves; but technical, contractual, economic, or regulatory uncertainties preclude such reserves being classified as proved. Unproved reserves may be further classified as probable reserves and possible reserves.

Unproved reserves may be estimated assuming future economic conditions different from those prevailing at the time of the estimate. The effect of possible future improvements in economic conditions and technological developments can be expressed by allocating appropriate quantities of reserves to the probable and possible classifications.

PROBABLE RESERVES

Probable reserves are those unproved reserves which analysis of geological and engineering data suggests are more likely than not to be recoverable. In this context, when probabilistic methods are used, there should be at least a 50% probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable reserves.

In general, probable reserves may include (1) reserves anticipated to be proved by normal step-out drilling where sub-surface control is inadequate to classify these reserves as proved, (2) reserves in formations that appear to be productive based on well log characteristics but lack core data or definitive tests and which are not analogous to producing or proved reservoirs in the area, (3) incremental reserves attributable to infill drilling that could have been classified as proved if closer statutory spacing had been approved at the time of the estimate, (4) reserves attributable to improved recovery methods that have been established by repeated commercially successful applications when (a) a project or pilot is planned but not in operation and (b) rock, fluid, and reservoir characteristics appear favorable for commercial application, (5) reserves in an area of the formation that appears to be separated from the proved area by faulting and the geologic interpretation indicates the subject area is structurally higher than the proved area, (6) reserves attributable to a future workover, treatment, re-treatment, change of equipment, or other mechanical procedures, where such procedure has not been proved successful in wells which exhibit similar behavior in analogous reservoirs, and (7) incremental reserves in proved reservoirs where an alternative interpretation of performance or volumetric data indicates more reserves than can be classified as proved.

POSSIBLE RESERVES

Possible reserves are those unproved reserves which analysi geological and engineering data suggests are less likely to recoverable than probable reserves. In this context, when probal tic methods are used, there should be at least a 10% probability the quantities actually recovered will equal or exceed the sun estimated proved plus probable plus possible reserves.

In general, possible reserves may include (1) reserves which, b on geological interpretations, could possibly exist beyond a classified as probable, (2) reserves in formations that appear t petroleum bearing based on log and core analysis but may no productive at commercial rates, (3) incremental reserves attribute infill drilling that are subject to technical uncertainty, (4) rese attributed to improved recovery methods when (a) a project or p is planned but not in operation and (b) rock, fluid, and reser characteristics are such that a reasonable doubt exists that the pro will be commercial, and (5) reserves in an area of the formation appears to be separated from the proved area by faulting geological interpretation indicates the subject area is structur lower than the proved area.

RESERVE STATUS CATEGORIES

Reserve status categories define the development and produ status of wells and reservoirs.

Developed: Developed reserves are expected to be recovered f existing wells including reserves behind pipe. Improved reco reserves are considered developed only after the necessary equipn has been installed, or when the costs to do so are relatively mi Developed reserves may be sub-categorized as producing or n producing.

Producing: Reserves subcategorized as producing are expecte be recovered from completion intervals which are open producing at the time of the estimate. Improved recovery rese are considered producing only after the improved recovery pro is in operation.

Non-producing: Reserves subcategorized as non-produc include shut-in and behind-pipe reserves. Shut-in reserves expected to be recovered from (1) completion intervals which open at the time of the estimate but which have not started proc ing, (2) wells which were shut-in for market conditions or pipe connections, or (3) wells not capable of production for mechan reasons. Behind-pipe reserves are expected to be recovered f zones in existing wells, which will require additional complet work or future recompletion prior to the start of production.

Undeveloped Reserves: Undeveloped reserves are expected to recovered: (1) from new wells on undrilled acreage, (2) f deepening existing wells to a different reservoir, or (3) wher relatively large expenditure is required to (a) recomplete an exist well or (b) install production or transportation facilities for prim or improved recovery projects.

Approved by the Board of Directors, Society of Petroleum Engineers (SPE) In the Executive Board, World Petroleum Congresses (WPC), March 1997

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Process
Cas
Panha
3D

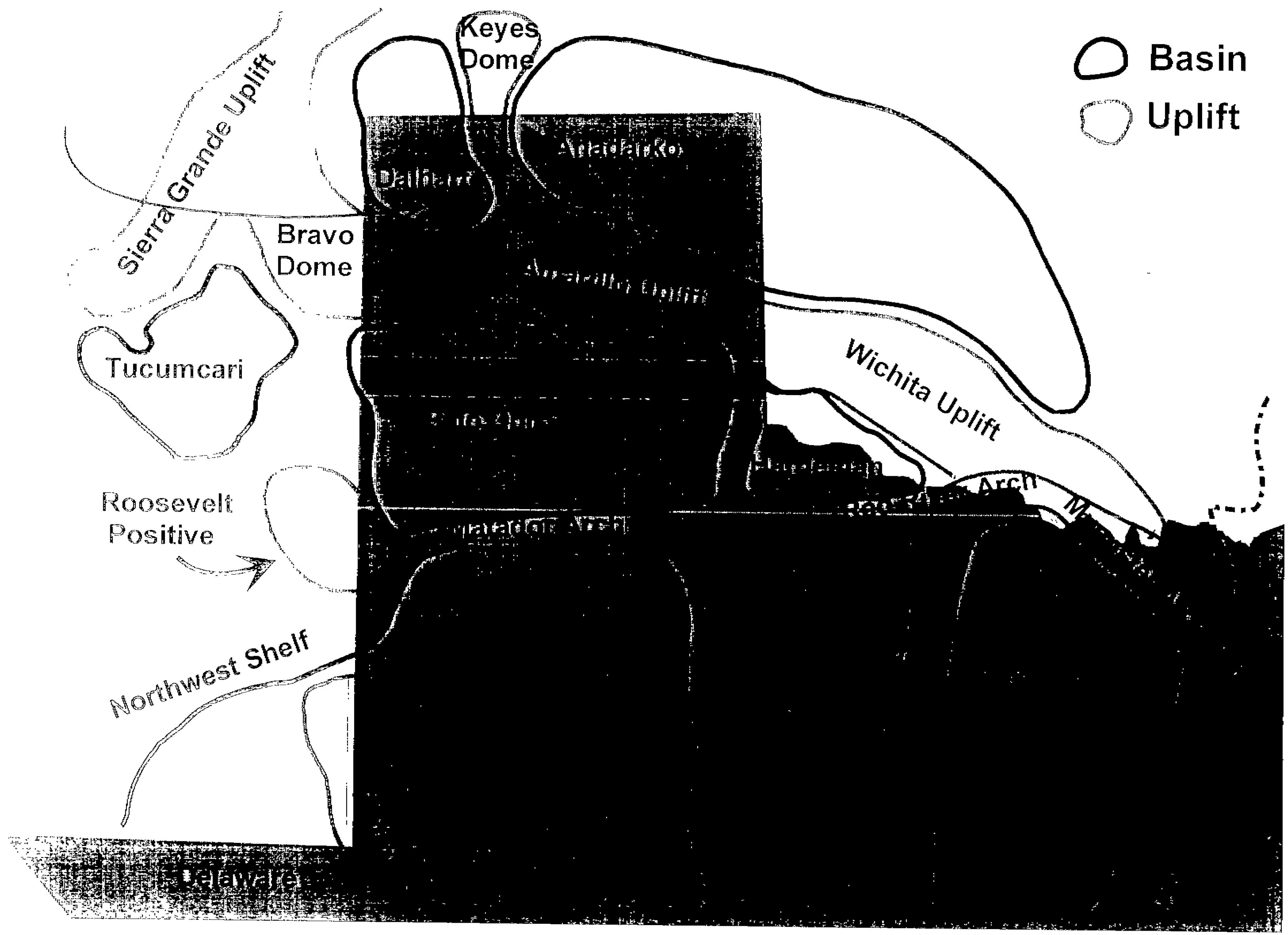
Processing Parameters

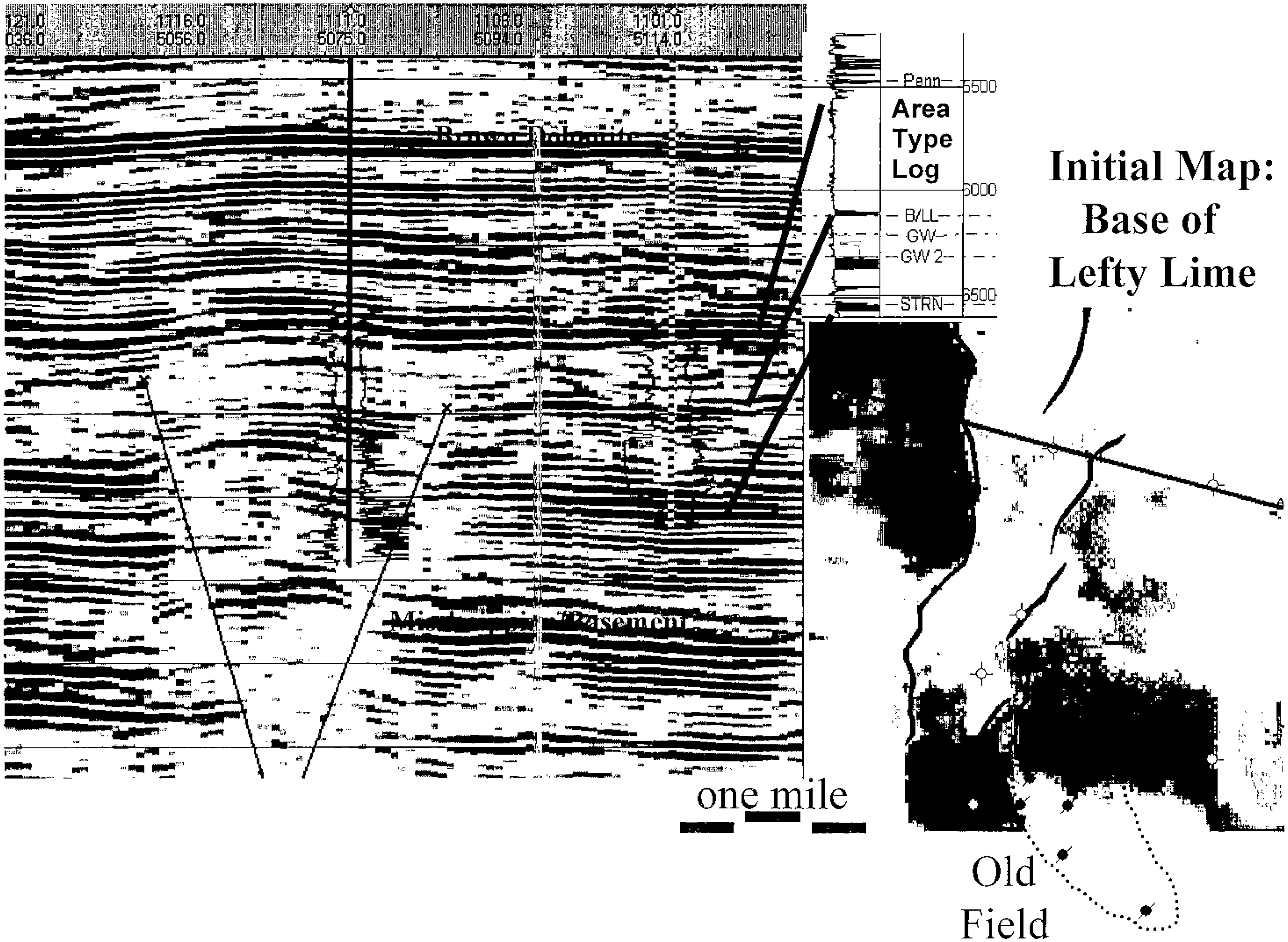
1994

1) Geometry, Gain Recovery
2) Surface Consistent Spiking Deconvolution
3) Pre-Stack Spectral Whitening
4) Pre-Stack Noise Removal
5) Refraction Statics
6) Velocity Analysis, Reflection Statics (2 passes)
7) 3D Dip Moveout
8) Velocity Analysis
9) NMO and Mute
10) Residual Statics
11) Stack
12) Spectral Whitening
13) Noise Removal
14) Migration

1998

1) Geometry, Gain Recovery
2) Refraction Statics
3) Surface Consistent Spiking Deconvolution
4) Velocity Analysis, Reflection Statics (2 passes)
5) Pre-Stack Spectral Whitening
6) Residual Statics
7) Dip Moveout
8) Velocity Analysis
9) Stack
10) Noise Removal
11) Migration
12) Spectral Whitening


Basin
Uplift
Keyes Dome
Dalhart
Anadarko
Amarillo Uplift
Sierra Grande Uplift
Bravo Dome
Tucumcari
Wichita Uplift
Arch
Roosevelt Positive
Northwest Shelf
Delaware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Base of
Lefty Lime
Area
Type
Log
Penn
B/LL
GW
GW 2
STRN
5500
6000
6500
121.0
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1116.0
5056.0
1111.0
5075.0
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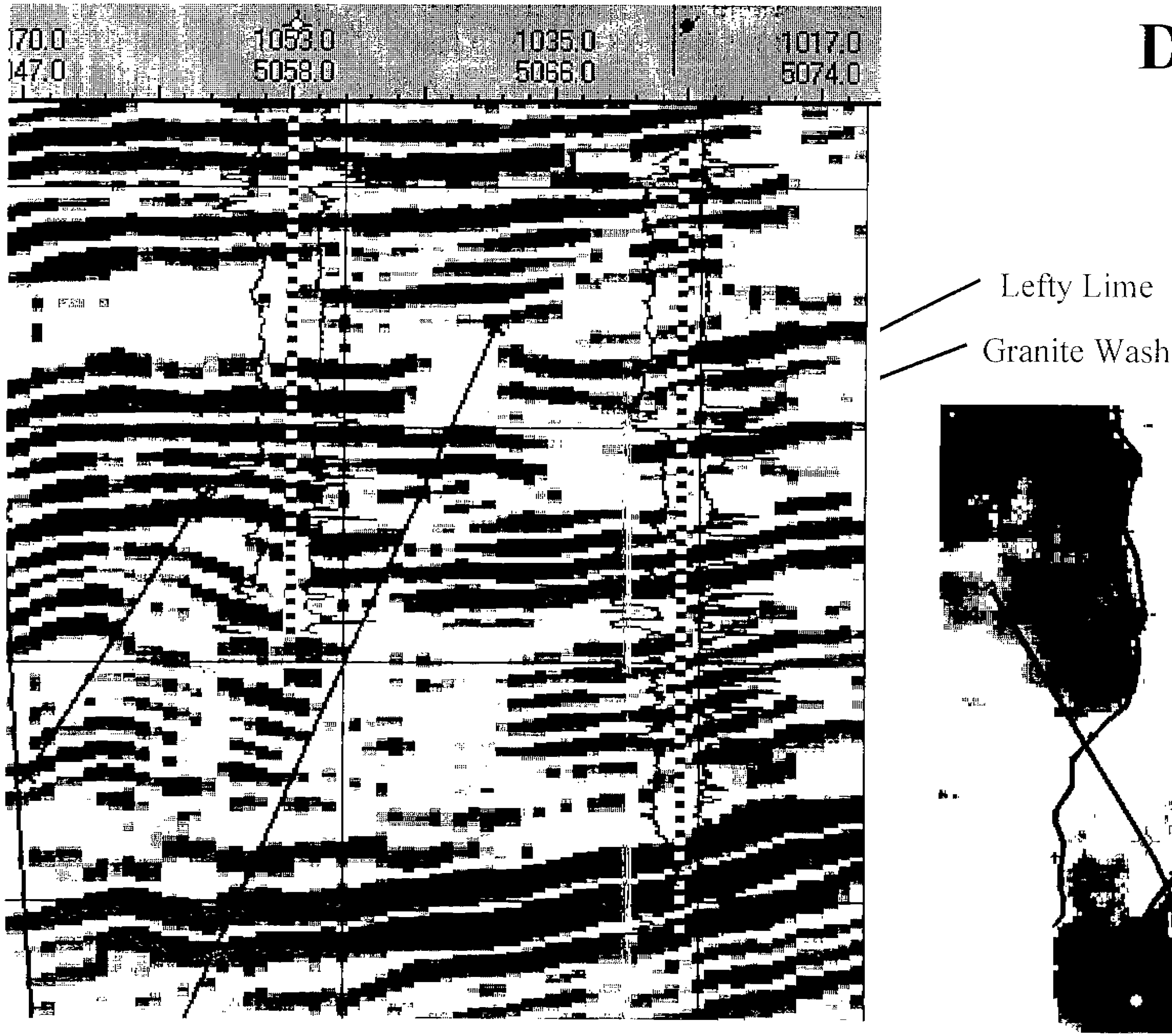
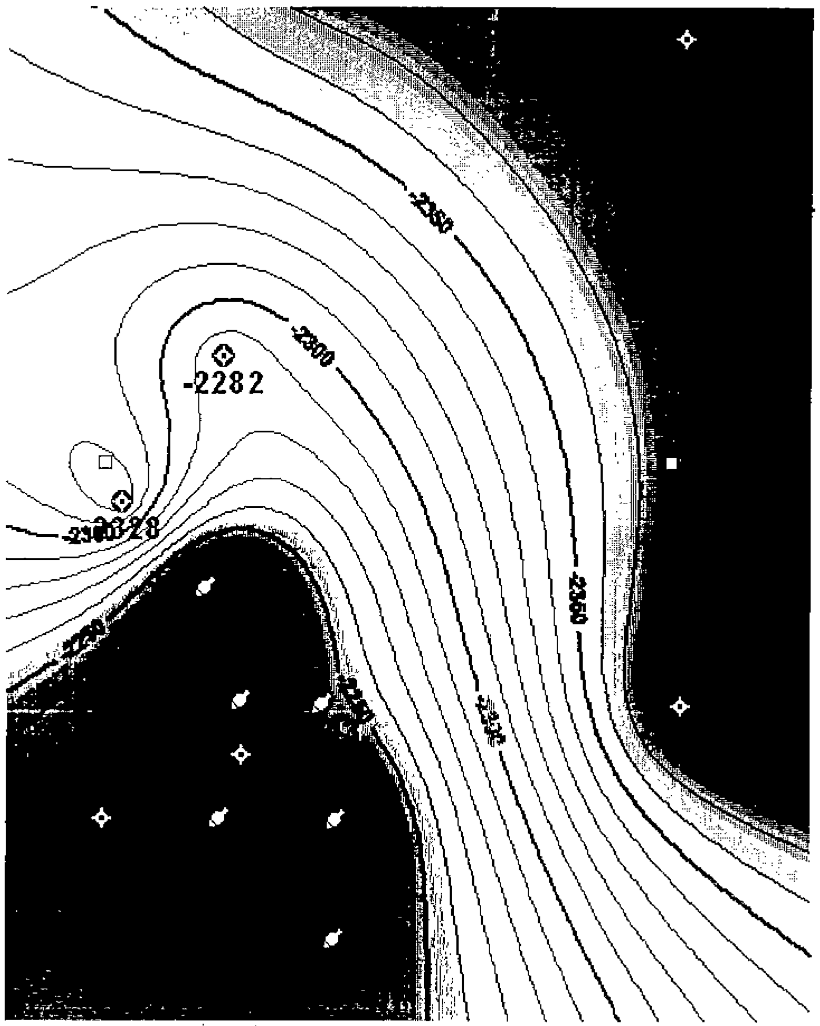
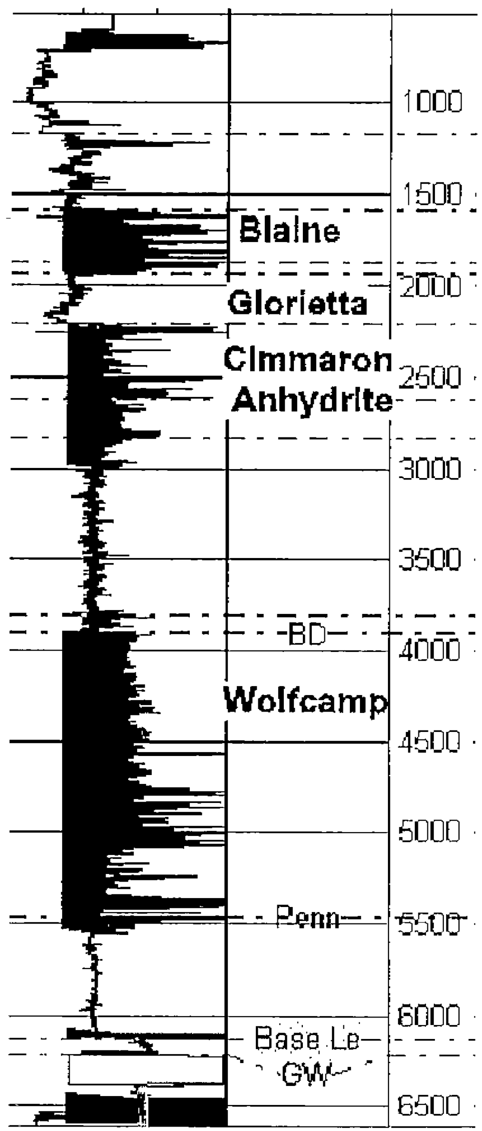
Basement
one mile
Old
Field

Development Prospect #1





Subsurface Map - Granite Wash



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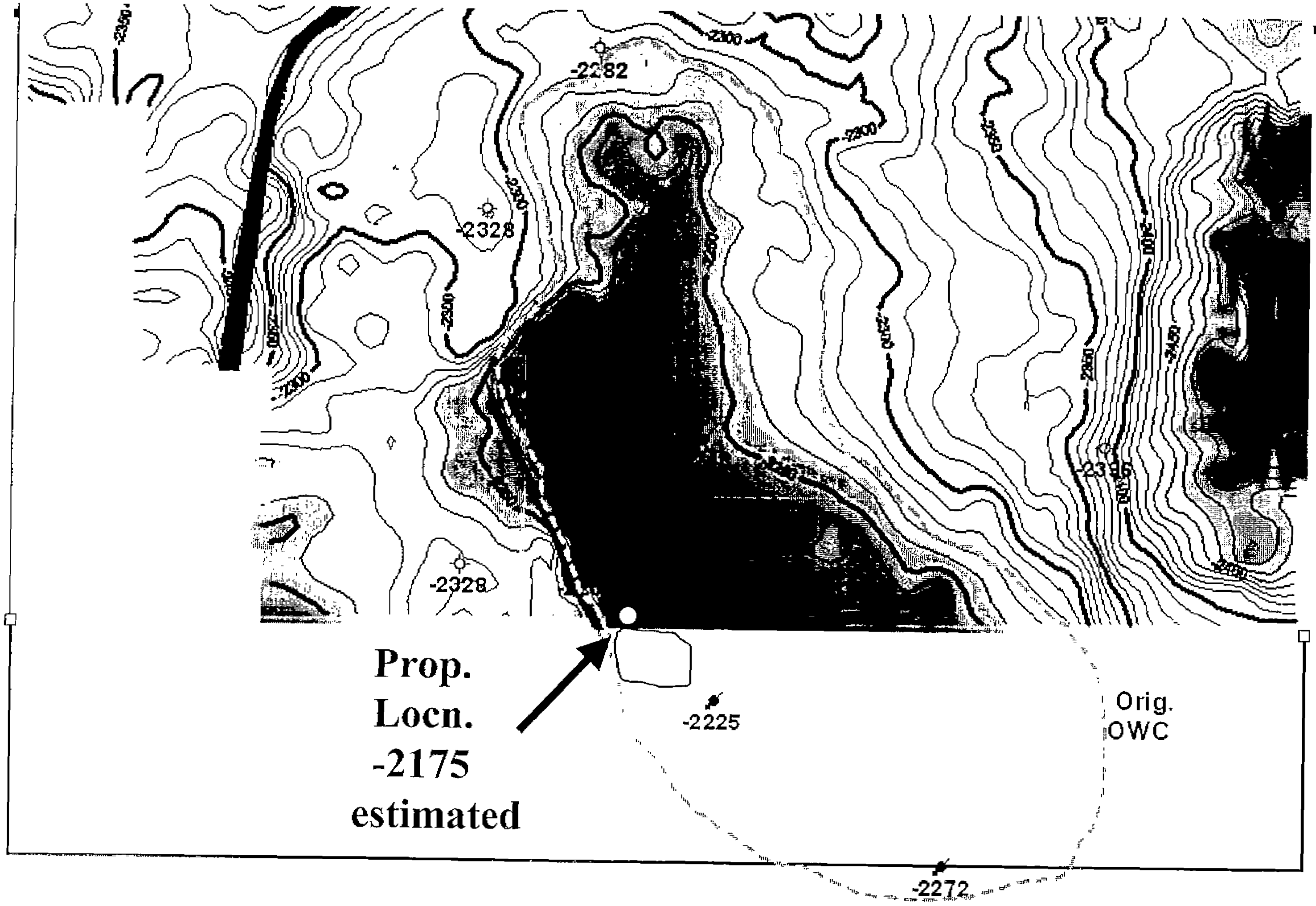
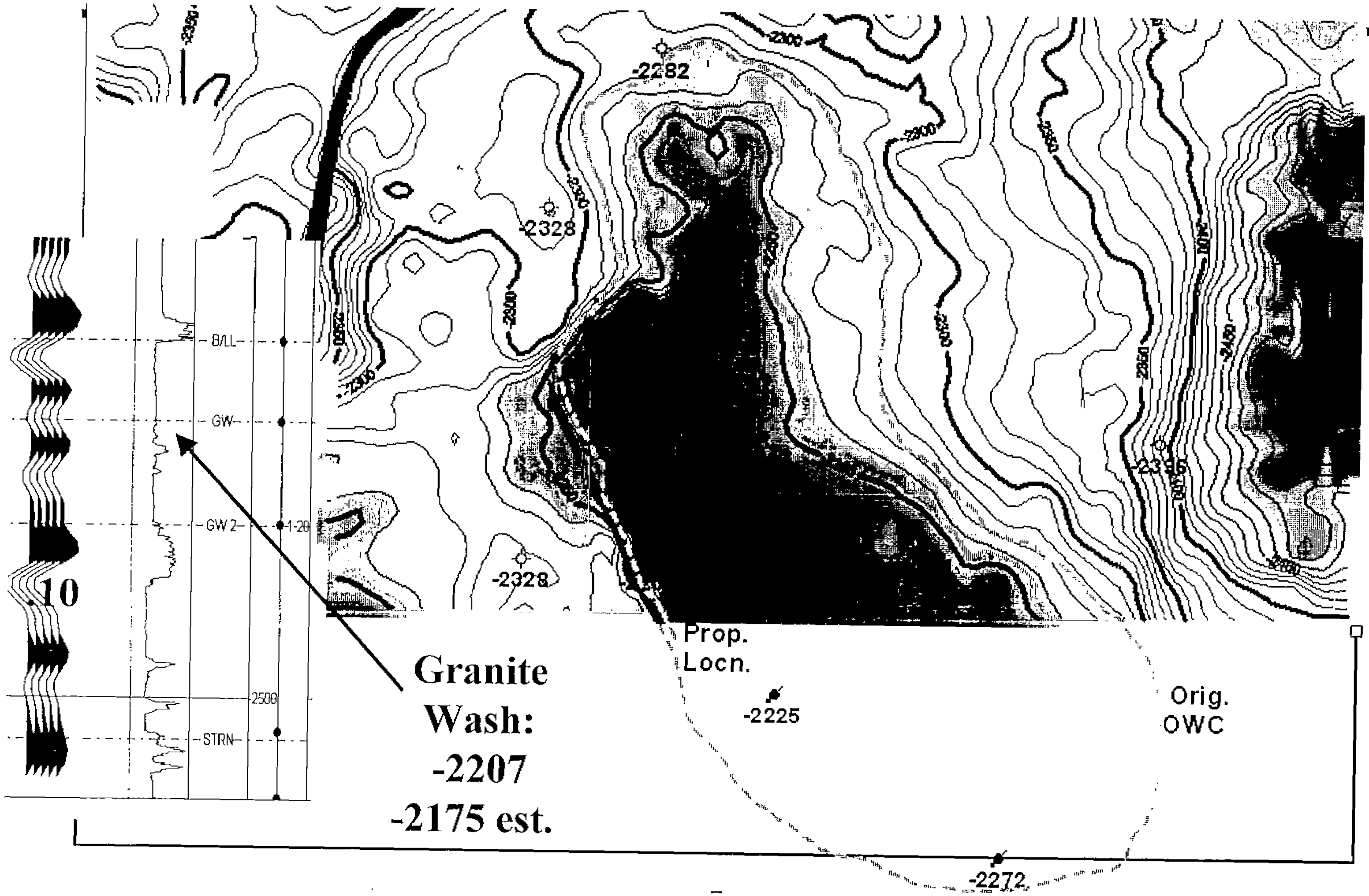
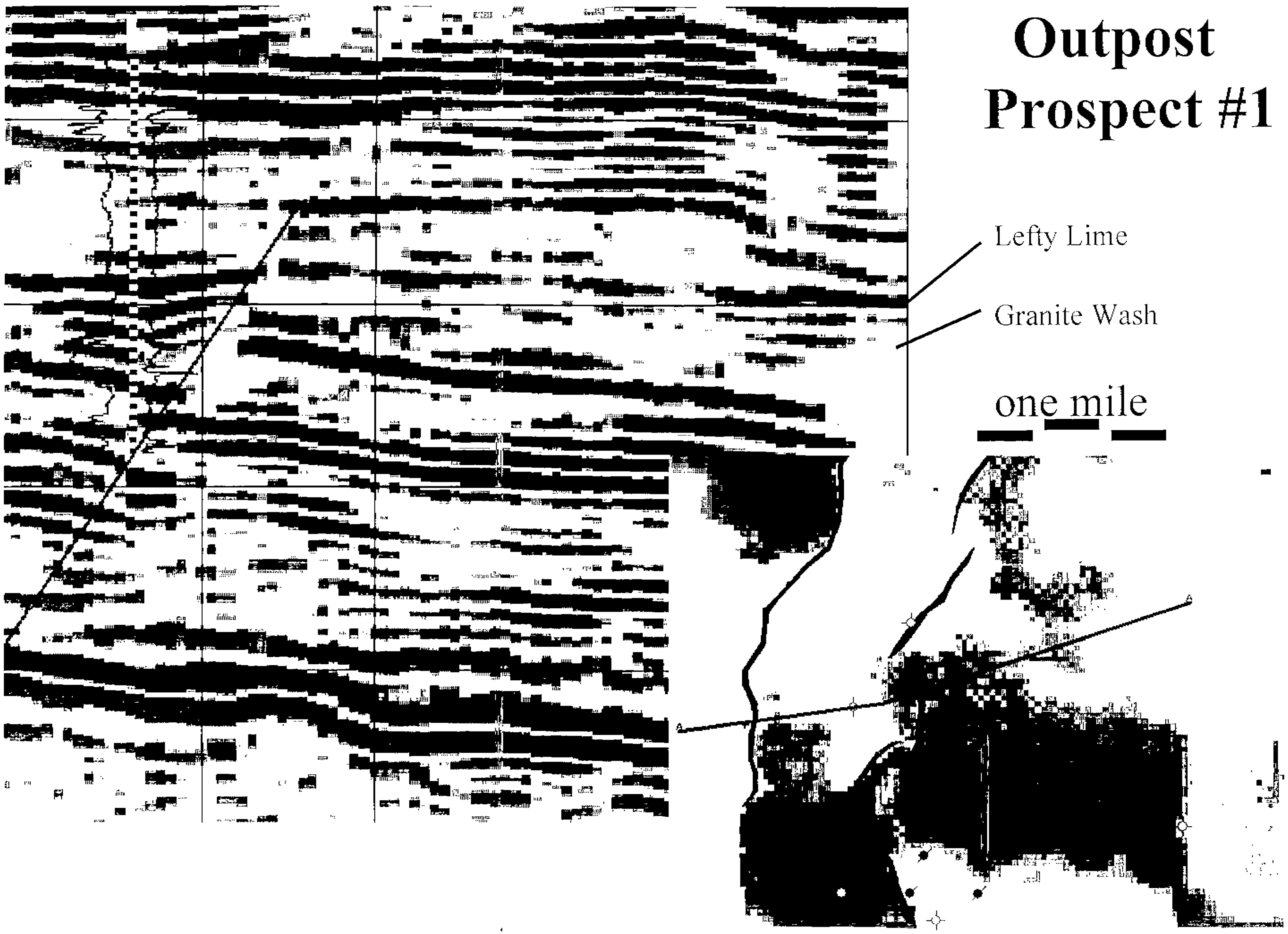


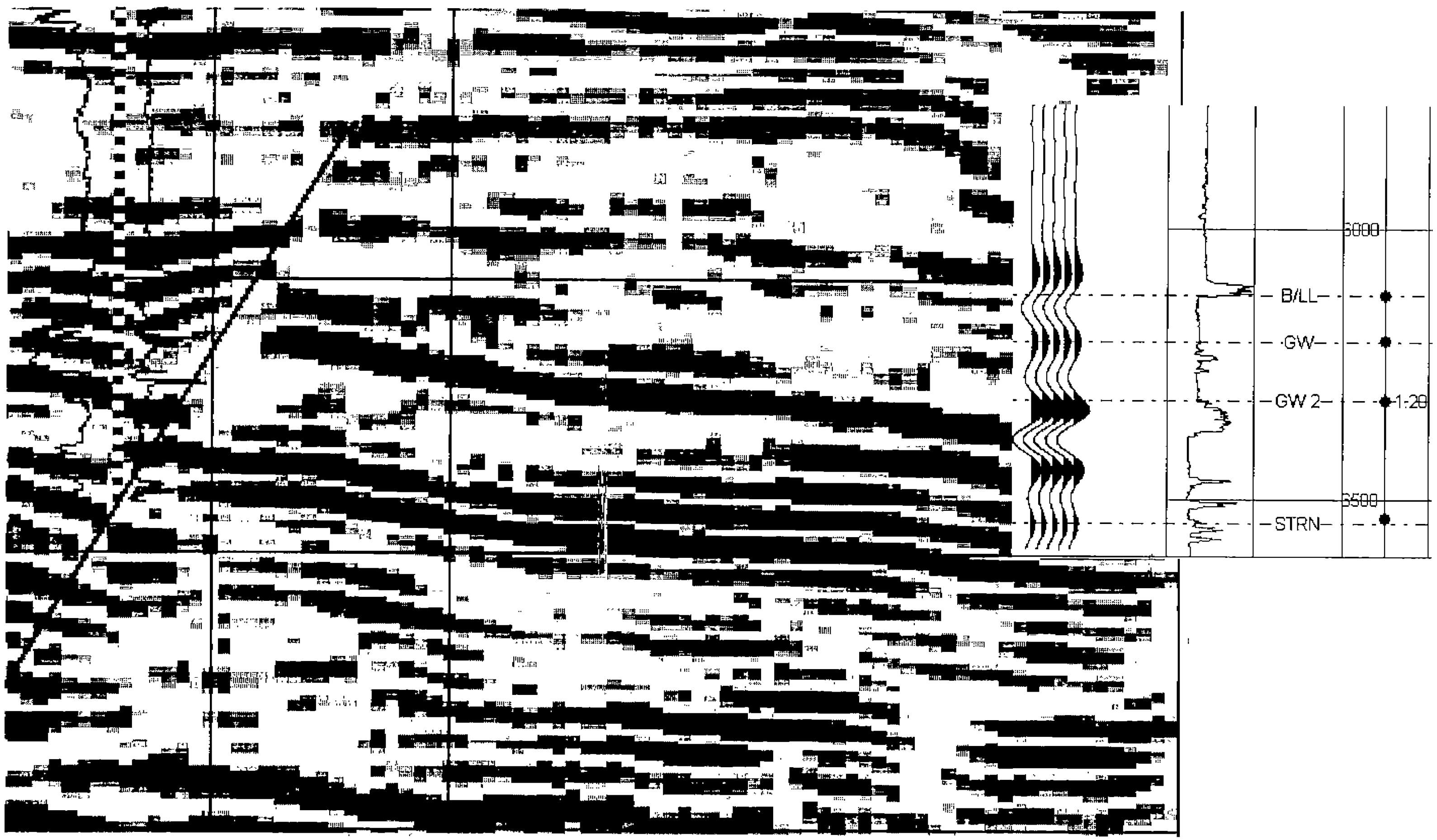
First Granite Wash Depth Map



First Granite Wash Depth Map

Outpost Prospect #1

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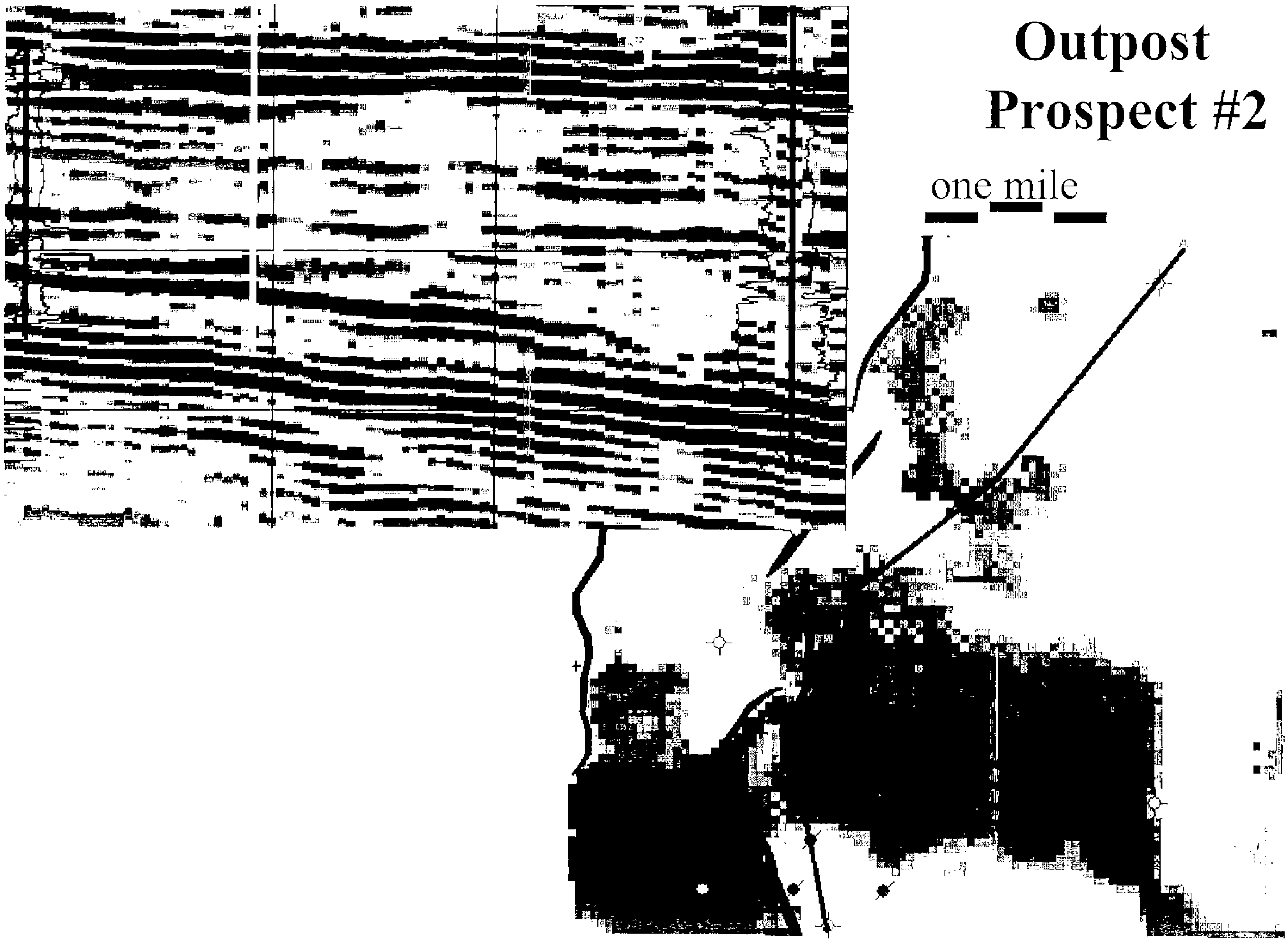
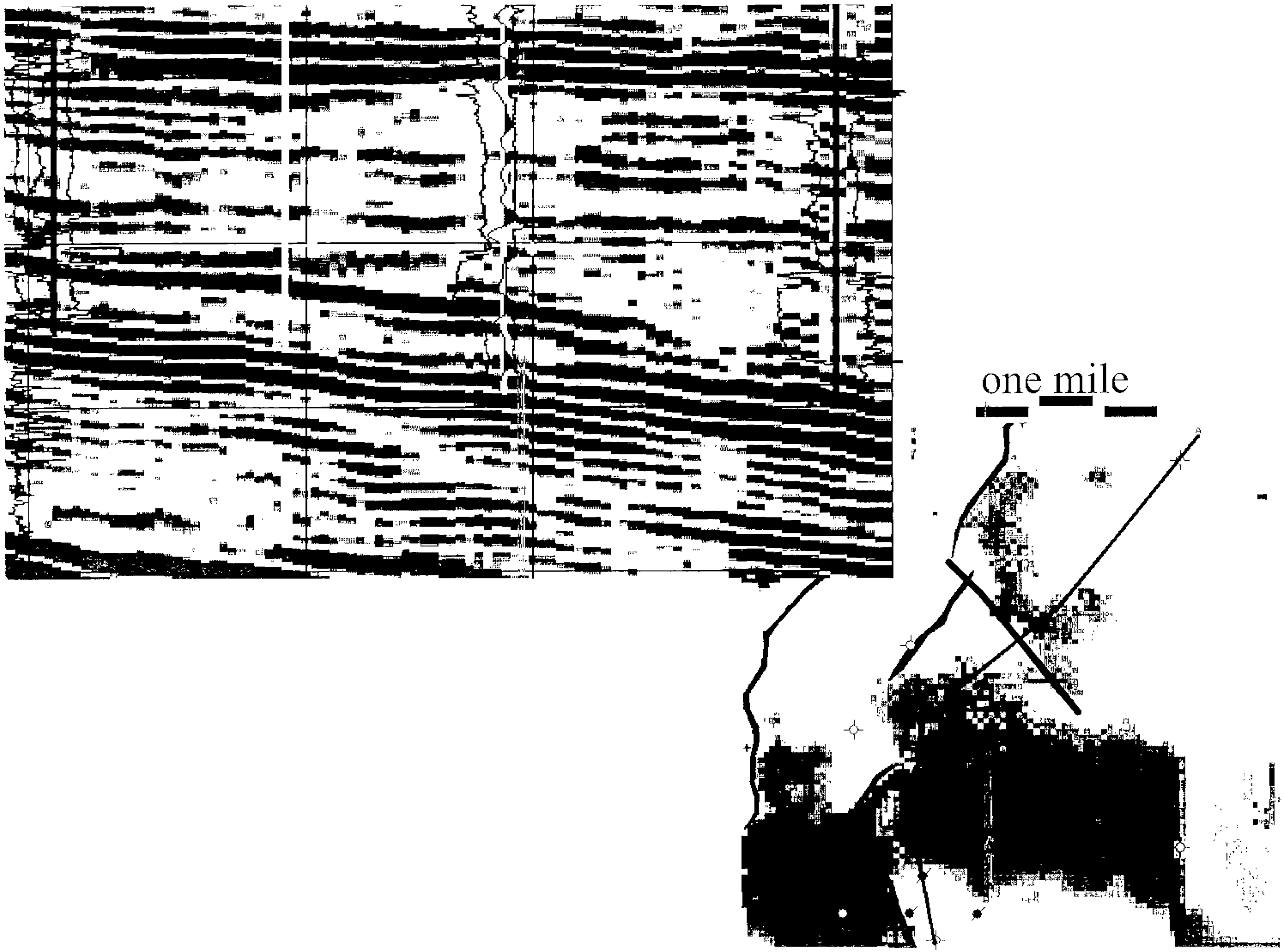
STRN

Outpost Prospect #2

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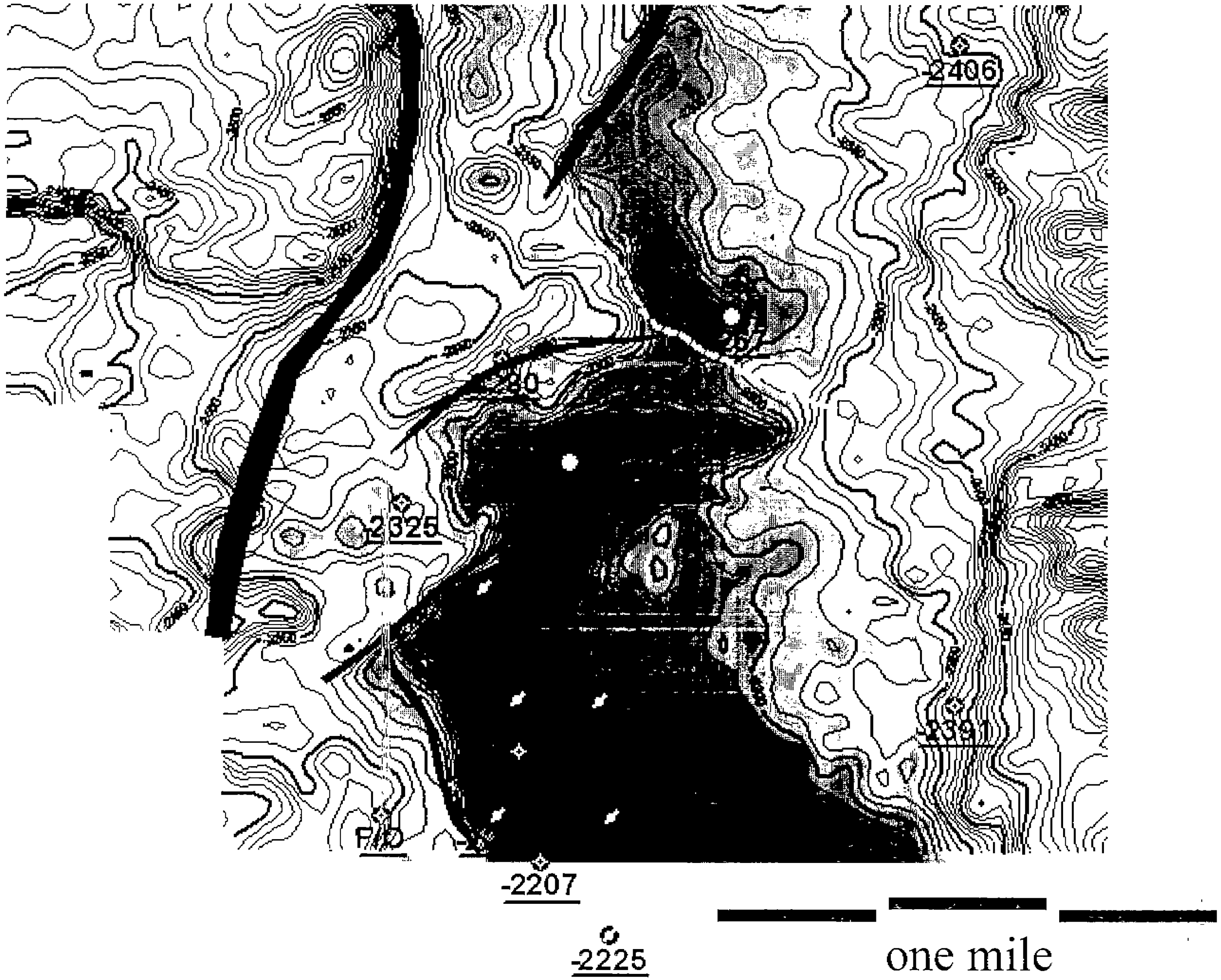
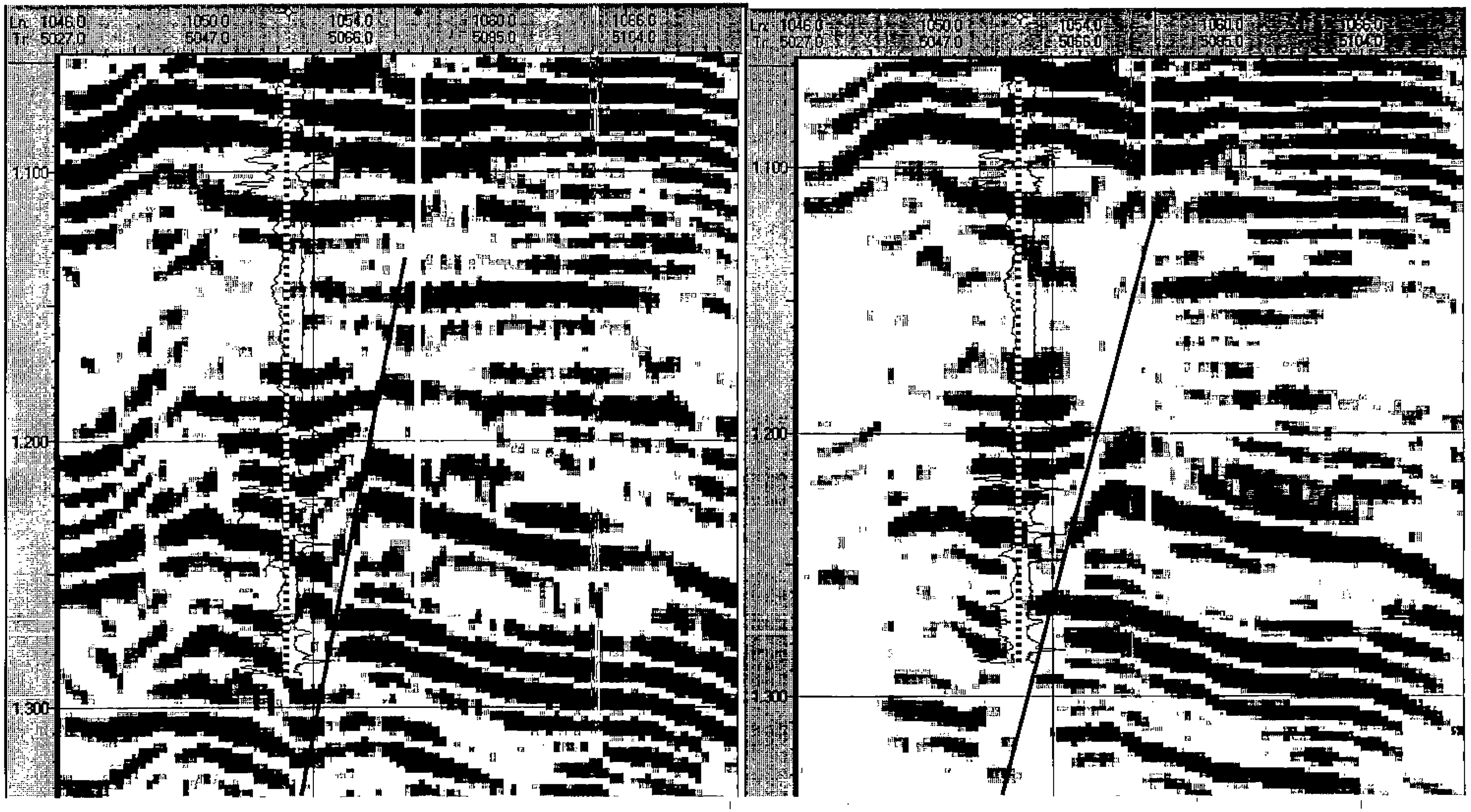
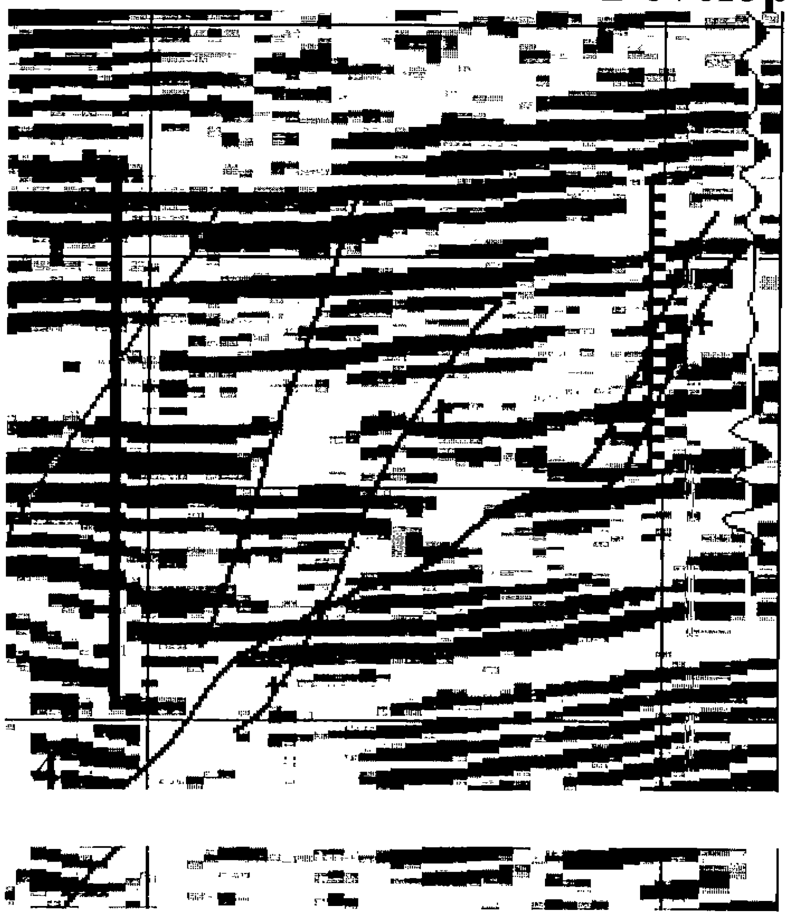


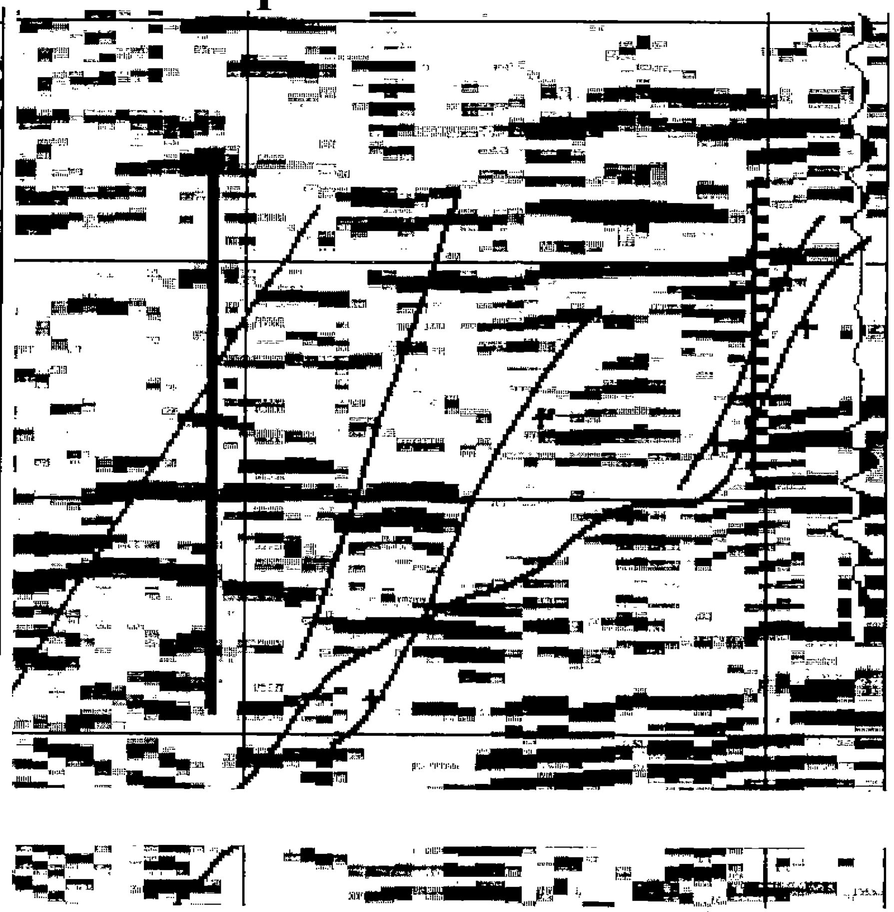
Granite Wash Revised Depth Map



With DMO | No DMO

Development Prospect #1

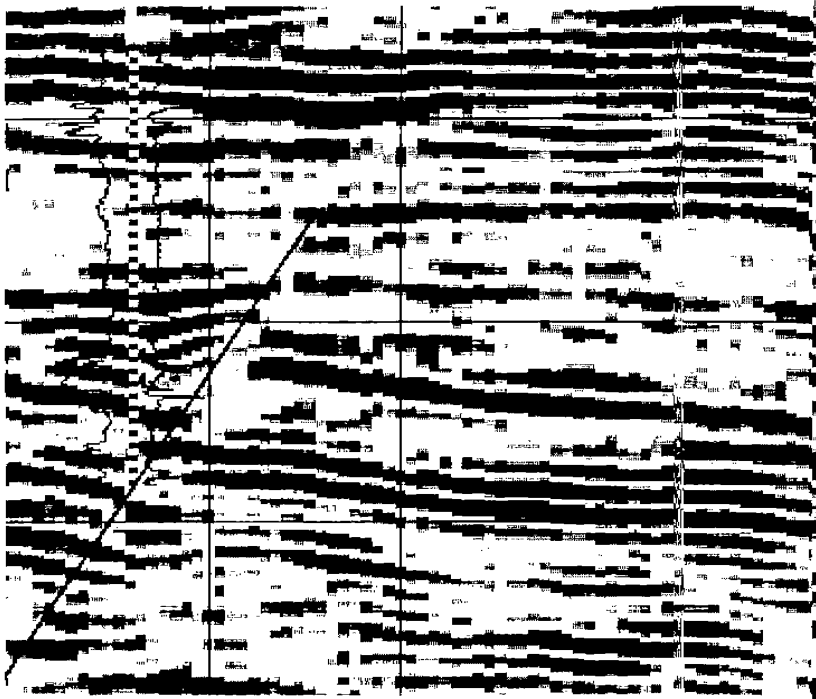




Original

Reprocessed

Outpost Prospect #1



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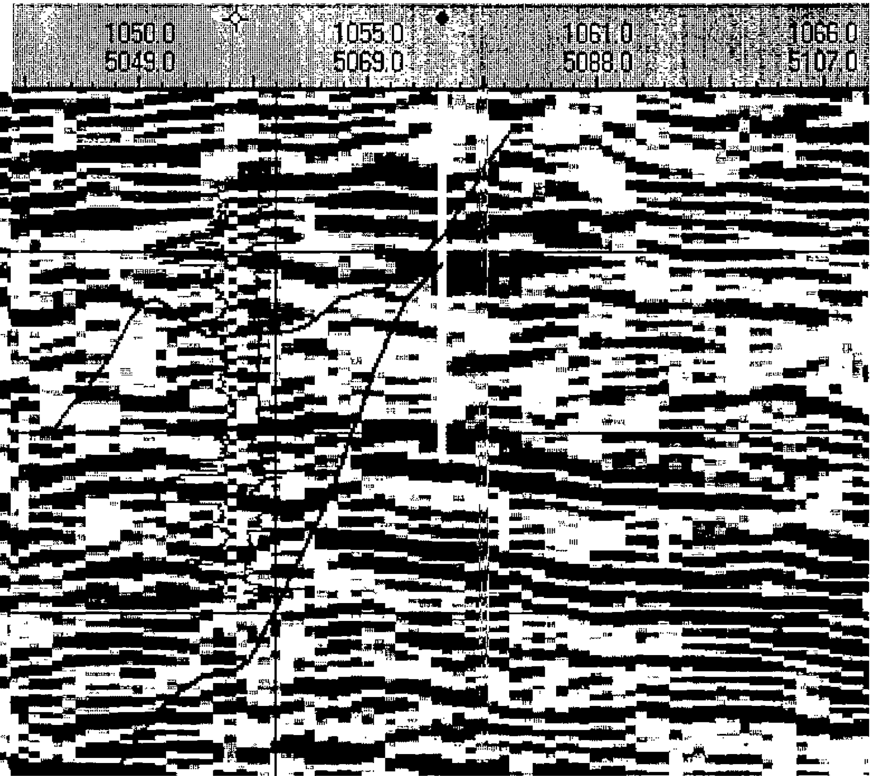

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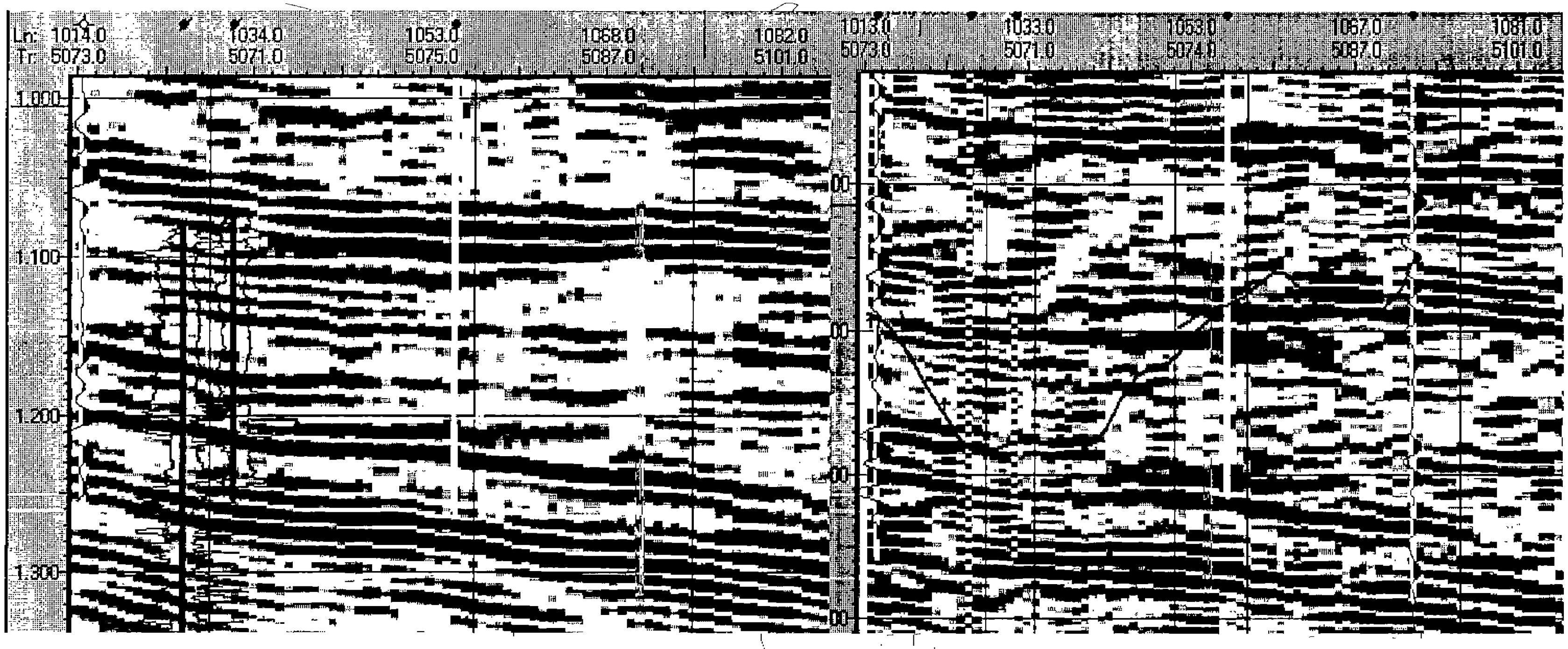
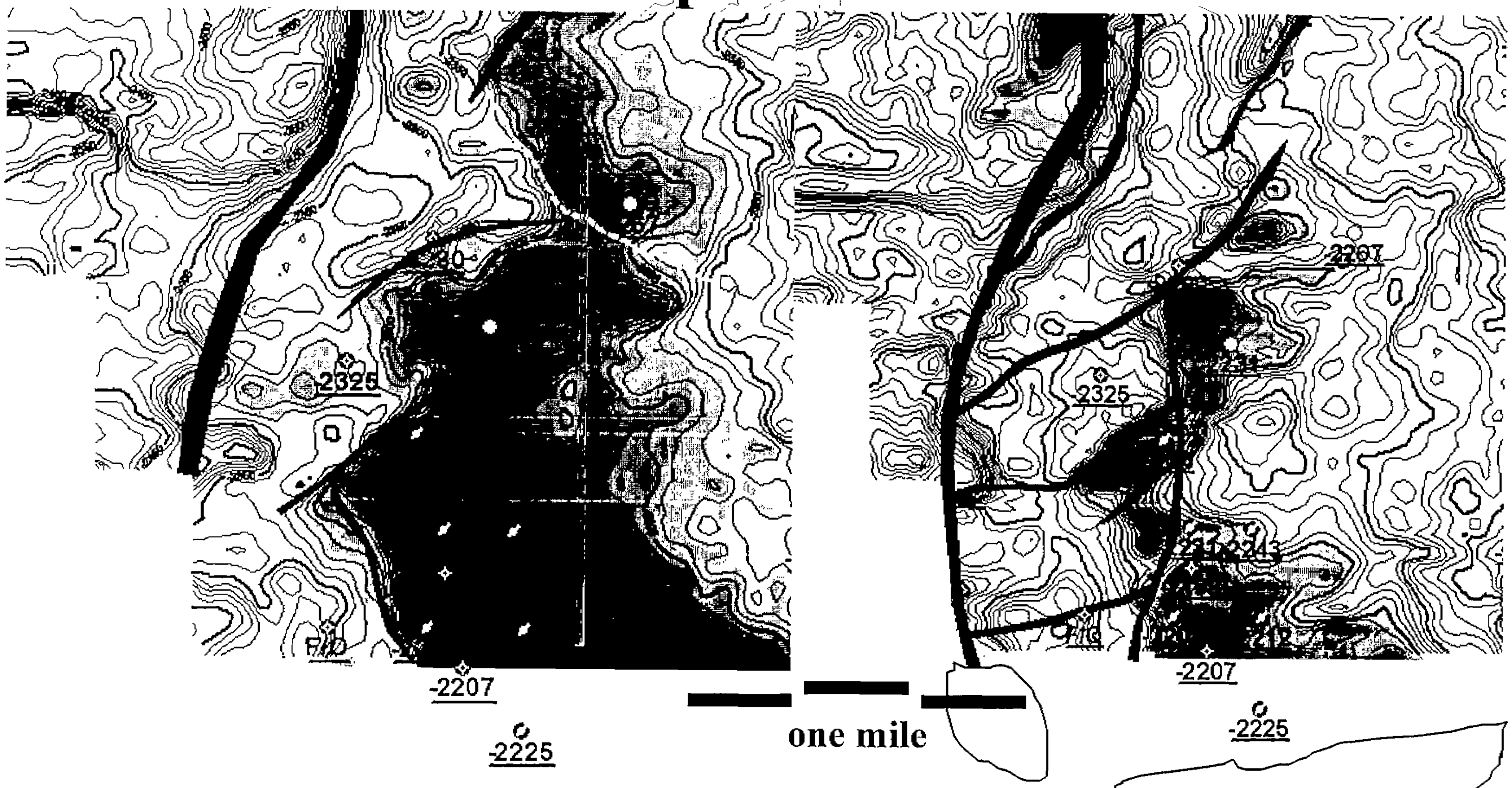
Outpost Prospect #2



Original

Reprocessed

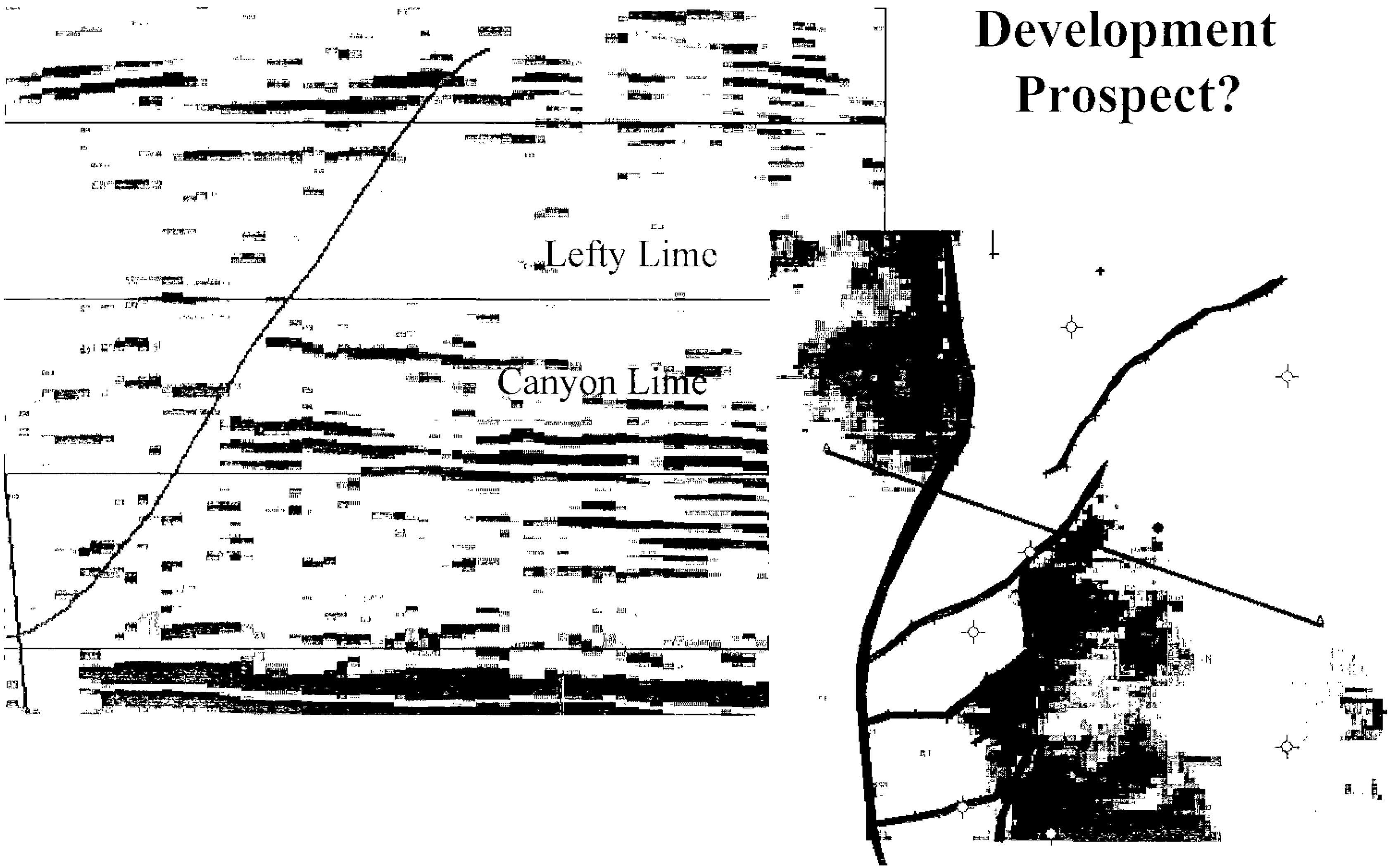
Top Granite Wash Comparison



Original Processing

Re-processing

Development Prospect?



Petroleum Technology Research Centre to Benefit Saskatchewan Oil Industry

When the walls of Regina's new Petroleum Technology Research Centre (PTRC) start to rise in 1999, they will rest on a solid foundation of productive partnerships between western Canada's oil industry and research organizations like the Saskatchewan Research Council (SRC). Funding from federal and provincial governments will help to mortar the bricks of enterprise and expertise.

Research carried out in new world-class laboratories will be dedicated to enhancing the production from and value of Saskatchewan's oil resources, particularly heavy crude, through the development of advanced technologies. The $11 million facility will enable ongoing efforts to reach unprecedented heights, thanks to the creative synergies of the working partners — SRC's Petroleum Branch and the University of Regina's Petroleum Engineering Group. The Centre will also act as a magnet for the development of new opportunities, leading to even greater sector growth.

Industry is intentionally assigned a leading role in guiding work done at the PTRC. Five of the 10 positions on the Board of Directors will be held by representatives of Saskatchewan's oilpatch. Frank Proto, retired president of Wascana Energy Inc., will chair the Board.

Oil companies operating in the province are also expected to invest vigorously in PTRC projects, providing up to $4 million annually. Novel technologies that solve the challenges of the province's oil resources are exactly what Saskatchewan Energy and Mines had in mind, when it announced the Saskatchewan Petroleum Research Incentive in April '98. Industry investment in laboratory research at the PTRC will qualify for up to $500,000 a year in royalty credits.

SRC's Petroleum Research in Saskatchewan: Milestones

1981	Saskatchewan's first petroleum research facilities established
1985	SRC acquires the facility and founds the Petroleum Branch
1988	Joint SRC-Industry Multiclient Research Program established
1997	MOU between SRC and U of R establishing joint professorship and sharing of facilities
2000	SRC's Petroleum Branch moves its operations to new PTRC

PTRC Facts and Figures

The Facility

- Located on Research Drive in the Regina Research Park, adjacent to the University of Regina (easy access for industry collaborators and field staff)
- Approximately 55,000 square feet
- Will house 50 staff (growing to 100 in a few years) comprising SRC's Petroleum Branch and the U of R's Petroleum Engineering Group. Links to SRC's Pipeline Technology Centre.
- 1st research facility in Canada to be built to C-2000 energy efficiency standards

Timetable

Sept. 1998	PTRC announced
October 1998	Board appointment
January 1999	Design complete
Early 1999	PTRC manager hired
March 1999	Tenders issued
Spring 2000	PTRC opens

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During its 18 years of operation, SRC's Petroleum Branch has enjoyed strong support from the oil industry. Because many of Saskatchewan's petroleum reserves are notoriously difficult to produce, the sector has long relied on R&D as a recovery tool. SRC has collaborated with industry on some of the most significant developments in the oilpatch.

Notably, SRC helped to design the province's first horizontal well project at Tangleflags North, and is providing a variety of vital studies for the massive CO_2 flood set to begin in Weyburn reservoir. Horizontal wells resuscitated production in the marginal heavy oil reservoirs of the Lloydminster-Kindersley region; province-wide this technology increased production by 36% and sustained 4,300 jobs. The Weyburn project is expected to recover 122 million barrels of light oil over 20 years and create 1,400 direct and spin-off jobs.

These recovery technologies will continue to be refined at the PTRC. Industry will also participate with its PTRC partners in research into methane flooding in heavy oil reservoirs, air injection (in-situ combustion), emulsion treatment, and field-scale upgrading technologies. With the Centre's expertise and infrastructure at its disposal, industry will also be able to identify and pursue entirely new opportunities.

Through the establishment of a degree program in petroleum engineering, the University of Regina has shown its commitment to advancing the sector. In 1996, SRC and the University of Regina signed an MOU to strengthen their already successful relationship. The agreement, among other things, provided for the co-funding of a petroleum professorship and close cooperation between their staffs. The aim was to advance their research capabilities and ultimately the profile and profitability of Saskatchewan's petroleum sector. The PTRC is perfectly positioned to fulfill that goal.

Total Capital Costs

$10.8 million for capital construction, divided as follows:

- $6 million non-repayable contribution, cost-shared by the federal and provincial governments through the Western Economic Partnership Agreement (first project approved under WEPA), administered by Western Economic Diversification Canada and Saskatchewan Economic and Co-operative Development
- $4.8 million from Saskatchewan Opportunities Corporation (SOCO), to be recouped in rent from building tenants

Operations

- The PTRC will be a separate legal entity, with each partner maintaining its independent status but collaborating closely with the other
- Ten Members of the Board, including the Chair, will provide strategic direction and promote industry support of research projects
- The Board will comprise a minimum of five industry representatives (including the Chair), and senior officials from Natural Resources Canada, Saskatchewan Energy and Mines, SRC and the U of R
- A group of technical experts will advise on the allocation of funds to research projects and the development of new research proposals
- A PTRC manager will be hired to coordinate participants' activities and market the PTRC's services

Government Support

As announced Sept. 3, 1998, the federal and provincial governments are committing the following operating funds over 5 years:

- Natural Resources Canada will provide $5 million, including support for at least 6 research professors
- Saskatchewan Energy and Mines will contribute $1 million, and up to $1.8 million through the Saskatchewan Petroleum Research Initiative
- The provincial government will also supply $7 million through funding to SRC

Petroleum

Multiclient Petroleum Research Program

We are driven by your petroleum...

By the vast quantity of the resource.

By the sheer challenge of getting it out of the ground.

By its less-than-ideal quality.

By its value to your company and to our economy and communities.

Oil companies are embracing the technological advances that are critical to improving production. We at SRC are doing some forward thinking of our own to anticipate and answer the industry's needs—from enhanced oil recovery techniques to innovative solutions to production problems.

From Reservoir to Refinery...

SRC has devised a research program that looks at the best bets for improving the bottom line of participating clients. Our applied R&D capabilities cover the industry's needs, from reservoir to refinery.

Our Research is Relevant

Because we work in partnership with oil companies, who help direct the research and have rapid access to results, our research is relevant to their needs.

In SRC's multiclient program, companies choose each year from a menu of six projects. A package fee lets them participate in all six at substantial savings.

Whether clients take part in one project or the whole package, they can be sure that, by pooling their R&D dollars with other companies with similar interests, they are getting a program of broad scope and impact.

1. **Horizontal Well Technology:** This project helps clients to effectively apply horizontal wells and achieve optimum performance from them, through improved reservoir engineering and drainage architectures. We are developing innovative recovery strategies using scaled physical modelling and numerical simulation of the reservoir.

2. **Heavy Oil Recovery by Methane Pressure Cycling:** We're developing a non-thermal EOR process for thin heavy oil reservoirs using methane injection. Laboratory studies include coreflood and PVT analyses and scaled physical modelling.

3. **Enhanced Recovery by Air Injection/In-Situ Combustion:** To improve forecasting of air injection, this project meshes oil analysis methods with techniques to predict performance. By reducing the expense and risk associated with field tests, reliable forecasting will become a valuable tool for increasing reserves.

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Petroleum

4. CO_2 **Injection in Light and Medium Oil Reservoirs:** Near-miscible flooding with carbon dioxide shows strong potential for Saskatchewan's LMO reservoirs. This project uses coreflood and PVT analyses and numerical simulation techniques to optimize the process. The goal is to maximize field recovery while lowering operating costs.

5. **Emulsions Research:** This project studies solutions to treating facility concerns, such as produced oil and slop oil treatment, demulsifier chemical quality control, and sand cleaning. We also develop ways to create emulsions for enhanced oil recovery and pipeline transportation of heavy oil.

6. **Development of Field Scale Upgrading Technology:** This project is developing low-cost, flexible technologies that will upgrade heavy oil to improve the quality and viscosity for pipelining and refining.

Facilities and Capabilities

Experimental studies are done in SRC's state-of-the-art petroleum laboratory in Regina and at our Pipeline Centre in Saskatoon. We have over a decade's experience in dedicated R&D for the oil industry. Our strengths lie in reservoir engineering, scaled physical and numerical modelling, and chemistry.

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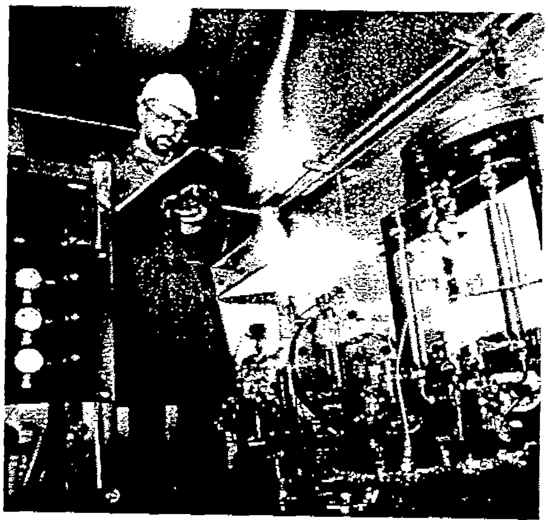
SRC Publication No P-110-339-C-96

Petroleum

Emulsions Research

A boom in petroleum production, particularly of heavy oil through enhanced recovery, has been matched by rising oilfield treating problems and costs. SRC's capabilities in emulsions research and heavy oil treatment help our clients improve their operating efficiencies and bottom line. Extensive on-site testing and consulting with field staff underpin comprehensive laboratory studies.



SRC's continuous mobile testing unit is routinely used for chemical and process testing in the field.

Motivation

To achieve profitable, efficient recovery of heavy oil, producers must tackle a range of operating problems. Enhanced recovery methods often produce heavy oil in the form of a tight water-in-oil emulsion. This requires demulsification for its water content to reach pipeline specifications. Conversely, creation of emulsions can provide opportunities for optimizing pipeline systems. Since 1981, SRC's Emulsion Research Program has expanded to take on new concerns, such as sand disposal, that our clients encounter at their treating facilities.

> *"We've expanded our program to take on new concerns that our clients encounter at their treating facilities."*

SRC Studies Solutions to Treating Facility Concerns

- **Treating Produced Oil** to lower its basic sediment and water (BS&W) to pipeline specifications
- **Slop Oil Treating** to break difficult emulsions in a novel wash process
- **Chemical Quality Monitoring** to identify plant upsets due to chemical variation and avert expensive bottle testing
- **Portable Sand Cleaning** for safe, economic disposal of produced sand

We also develop ways to create emulsions for

- enhanced oil recovery
- pipeline transportation of heavy oil

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Program Goals

Demulsification

- Slop oil treatment: develop wash treating process to separate slop oil into constituents, incorporate into battery operation
- Production Equipment Optimization: reduce load on treating vessels by pretreatment with coalescer columns and hydrocyclones; develop alternative water-handling processes (induced gas flotation, slime bed reactor)

Sand Cleaning

- Develop portable process to clean produced sand, allowing inexpensive disposal

Chemical Quality Monitoring

- To confirm the quality and consistency of treating chemicals, use high-performance liquid chromatography (HPLC). This averts costly and repetitive bottle-testing.

Combined Oil and Water Pipelining

- Optimize designs for "pushwater" pipelines that minimize pressure drop and thus capital and operating costs.

This project is part of SRC's Multiclient Petroleum Research Program. To find out more, contact

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SRC Publication No. P-110-340-G-96

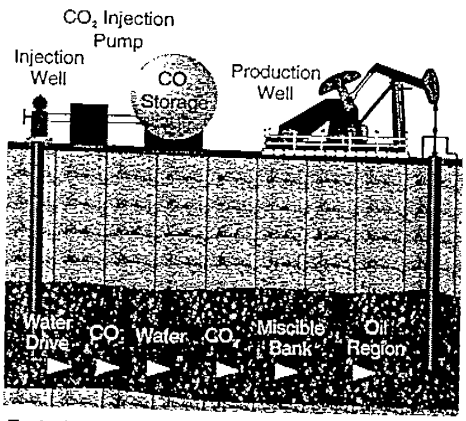
Petroleum

CO_2 Injection in Light and Medium Oil Reservoirs

Carbon dioxide injection can revive production in light and medium oil (LMO) reservoirs where conventional recovery methods are close to their economic limits. SRC helps clients to adapt the advantages of this enhanced oil recovery technique to a range of reservoir conditions, notably pressure constraints. CO_2 flooding could triple reserves and add two decades to the productive lives of post-waterflood fields.

Our Point of Departure

Even after 20 years under successful waterflooding, Saskatchewan's LMO reservoirs still retain over 70 percent of the initial oil, well over a billion cubic metres. A well-designed CO_2 flood could tap up to 25 percent of that resource and prolong the payback on producers' investment.



Typical water-alternating-CO_2 injection process

The Pressure Point

Operating pressure is a key design parameter, since many LMO reservoirs can't sustain the high pressures needed for the injected CO_2 to dissolve completely into the oil. For these reservoirs, SRC is designing effective strategies for near-miscible or immiscible displacement to deliver the benefits of CO_2 flooding. In higher pressure reservoirs, miscibility boosts recovery by greatly reducing interfacial tension, and swelling the oil and lowering its viscosity.

"CO_2 injection could triple reserves and add 20 years to the productive lives of post-waterflood fields."

What the Process Promises

- Increased reserves and field life
- Improved sweep and recovery efficiency
- Prolonged return on investment
- Flexibility of implementation
- Environmental benefits through storing of greenhouse gases

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SRC's Technical Approach

Since this project began in 1988, SRC has aimed at expanding the effectiveness and applicability of CO_2 injection by

- Helping clients screen reservoirs for their suitability to the process
- Providing reliable data, such as minimum miscibility pressure (MMP), to aid in optimizing field operating procedures and predict recovery
- Tailoring the process's injection strategy and well pattern to a given reservoir
- Identifying and solving potential production problems
- Studying the effect of reservoir depletion on MMP and oil recovery
- Studying the effect of contaminants in CO_2 on reservoir performance

Our Research Covers

- Phase behaviour (PVT) studies
- MMP measurements for oil-solvent systems
- Quantification of CO_2-induced organic precipitation
- Laboratory corefloods to assess recovery potential
- Numerical simulation to predict reservoir performance

This project is part of SRC's Multiclient Petroleum Research Program. To find out more, contact

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Petroleum

Development of Field Scale Upgrading Technology

Field scale upgrading offers an attractive option for heavy oil producers seeking a hedge against price swings, and hemmed in by market limitations posed by existing upgrading capacity. SRC is pursuing development of effective upgrading technology that can be rapidly applied with lower investment, allowing our clients to expand their markets for an improved product.

> *"Producers need simple, effective upgrading technology to safeguard their markets and ensure reasonable differentials"*

Background

Enhanced recovery techniques have made it possible for companies to increase their heavy oil production. The resulting crude is evermore in need of upgrading; meanwhile, the volumes coming on stream could glut capacity at existing large-scale upgraders/refiners. It's unlikely this capacity will be expanded in the near term because of the large capital investment needed.

Mounting production means a return is looming to higher price differentials between heavy and light oil; these have threatened the economic health of heavy oil producers in the past. New upgrading technology needing less investment and time to apply will have to be developed to carve a window of opportunity in this vicious circle.

Project Objectives

- To safeguard markets for heavy oil producers and ensure reasonable differentials over the near term
- To develop an effective heavy oil upgrading technology that can be used in small-scale applications
- To reduce need for condensate, and thereby free up pipeline capacity
- To provide a technology whose product has significant value in the market, by virtue of improved viscosity and density, and greatly reduced sulphur and nitrogen

Promising Technology

No simple upgrading technology currently exists but SRC is working to change that. Our experimental program focuses on supercritical water–oil reactions as the most promising option. This has provided viscosity reductions and density improvements; future work will continue to improve product quality and process economics.

This project is part of SRC's Multiclient Petroleum Research Program. To find out more, contact

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Petroleum

Horizontal Well Technology

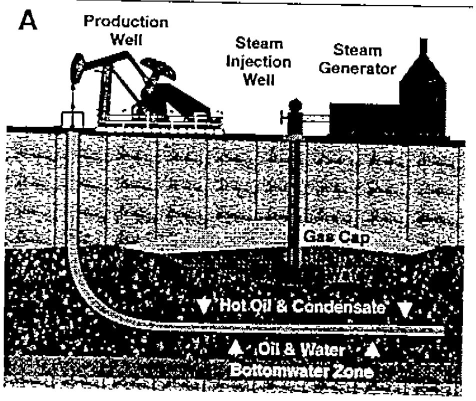
Horizontal well technology enables the petroleum industry to design new drainage architectures that can take advantage of specific reservoir settings and recovery techniques. SRC is advancing the application of this technology in heavy oil reservoirs by developing synergistic horizontal well/enhanced oil recovery processes, helping our clients to cut costs, boost production, and add reserves.

The Challenge

✓ Develop synergistic horizontal well/EOR processes to *increase production and profitability*

✓ Solve production problems that restrict application of horizontal well developments *to broaden resource base and reduce operating costs*

✓ Develop the tools needed to evaluate horizontal well applications *to improve reservoir management*

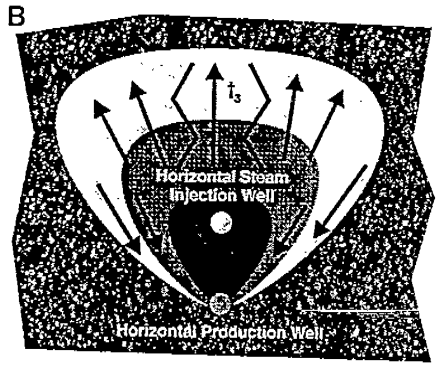


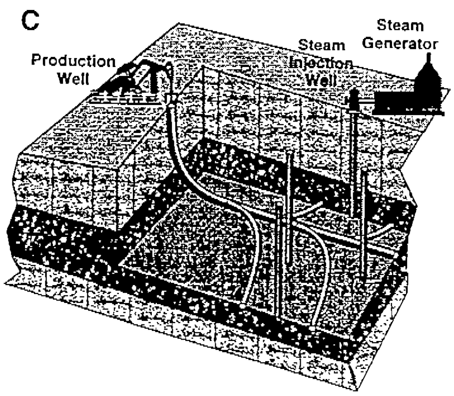
The evolution of heavy oil horizontal well technology showing A) classic horizontal well steam drive, B) steam-assisted gravity drainage (SAGD), C) multilateral configurations. SRC complements scaled physical modelling with numerical simulation to develop the best horizontal well/EOR application for a given reservoir setting.

The Lure

Heavy oil reservoirs are the greatest source of petroleum in Canada but they don't readily yield their riches. Horizontal wells have expanded the prospects for heavy oil production, sustaining primary recovery and making enhanced recovery a profitable possibility, even under such difficult conditions as

- active bottomwater, gas cap or both
- thin pay zone
- extremely viscous oil





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Program Objectives

Develop synergistic horizontal well/EOR processes

- Use new drainage architecture to enhance steam injection process for range of reservoir settings
- Further develop the steam crest oil resaturation (SCOR) process for active bottomwater reservoirs
- Evaluate steam-assisted gravity drainage (SAGD) and its variations to determine their optimal application
- Develop horizontal well/EOR techniques for thin reservoirs

Solve production problems that restrict the application of horizontal well development

- Develop continuous sand cleanout system to maintain high oil production rate and eliminate expensive wellbore cleanouts

Develop the tools needed to evaluate horizontal well applications

- Combine strengths of scaled physical modelling and numerical simulation to evaluate and predict reservoir performance
- Develop model to make critical prediction of wellbore flow regime and corresponding pressure drop

SRC's Expertise and Facilities

✓ SRC helped design Saskatchewan's first horizontal well project at Tangleflags North

✓ Fully equipped laboratory to conduct scaled physical model studies

✓ SRC Pipeline Technology Centre in Saskatoon equipped with 50-mm and 100-mm diameter pipeline flow loops to study multiphase horizontal wellbore flow and sand accumulation and transport problems

✓ Innovative numerical simulation capabilities

✓ Conducted numerous reservoir-specific (one-on-one) evaluations for members of the multiclient program

This project is part of SRC's Multiclient Petroleum Research Program. To find out more, contact

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SRC Publication No. P-110-343-C-96

Petroleum

Improved Oil Recovery by Air Injection

Novel Developments for In-Situ Combustion

SRC is pioneering techniques for predicting the performance of oilfields under air injection. With reliable forecasting, new operating strategies can be developed for the economic, large-scale production of otherwise unrecoverable oil.

"Increased recovery in difficult reservoirs"

Improved Techniques

Recent case histories have shown that new strategies for operating air injection projects can yield attractive performance results. The improvements are often most evident in what are otherwise difficult reservoirs.

For heavy oil, these improvements involve:

- Pressure cycling
- Horizontal wells

Other field trials have demonstrated success in deep light oil reservoirs.

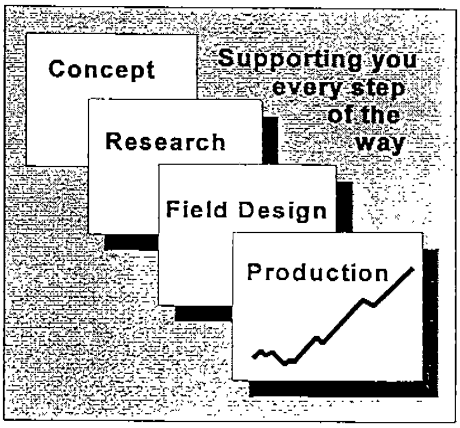
SRC's Technical Contribution

SRC is bridging the last two gaps on the road to performance prediction for in-situ combustion:

1. Description of the chemical reactions
    - A modified SARA (saturates, aromatics, resins, and asphaltenes) analysis provides a good representation of the different reaction types
    - Adaptable to different reservoirs
2. Numerical simulation techniques
    - Developing two-step approach for commercial simulators

SRC's Expertise

With over a decade of development and research experience, SRC has established a well-equipped in-situ combustion laboratory. It is operated by seasoned personnel working in a tradition of open, co-operative support of petroleum companies. Clients help to steer research along relevant and promising avenues.



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Related Services

Low-pressure combustion tube tests can be performed efficiently on a highly automated tube. In addition, thermal gravimetric analysis (TGA) and differential scanning calorimetry (DSC) tests can be performed for a variety of applications.

This project is part of SRC's Multiclient Petroleum Research Program. To find out more, contact

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Petroleum

SRC Publication No P-110-345-G-96

Petroleum

Methane Pressure Cycling Process with Horizontal Wells for Heavy Oil Reservoirs

Immiscible methane injection is a practical, low-cost solution to heavy oil recovery from thin reservoirs where thermal methods won't work. This flexible EOR process uses the reservoir-produced gas and exploits existing facilities, extending returns on investment. SRC is continually innovating gas flooding by, for example, integrating the benefits of horizontal wells and pressure cycling. We help clients optimize the injection strategy and well pattern to their reservoir conditions.

"A practical, low-cost solution to recovery from thin heavy oil reservoirs"

Motivation

Much of Canada's heavy oil resource is found in reservoirs with pay zones of less than seven metres, which are unsuited to thermal recovery methods and often characterized by bottom-water or low pressure. Conventional techniques have tapped less than 10 percent of the initial-oil-in-place of such fields. Immiscible methane injection is an enhanced recovery method that will allow operators to deliver on this huge potential for profitable recovery.

Why Methane Injection is Right for Thin Heavy Oil Reservoirs

✓ **Non-Thermal Process:** excessive heat loss makes thermal methods unsuitable

✓ **Low-Cost:** maximizes return on capital investment by using existing wells and gas-handling facilities

✓ **Low-Input:** uses and recycles available methane or produced gas

✓ **Improved Sweep Efficiency:** provided by pressure cycling the methane injection and by horizontal infill wells

✓ **Flexible:** can be adapted to a range of reservoirs types and integrated with other recovery processes such as steamflooding

SRC's Technical Approach

- **Reservoir Screening:** is a given reservoir a good candidate for methane flooding?
- **Injection Strategy:** how do we optimize it to improve the utilization efficiency of the gas and provide the best recovery?
- **Well Configurations:** when a horizontal infill well is used, what's the best length and location for it to improve sweep efficiency?

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SRC's Expertise and Facilities

✓ A decade of experience in studying immiscible gas injection

✓ PVT apparatus to study phase behaviour of reservoir fluids

✓ 1-D coreflood to evaluate displacement efficiency and mechanisms

✓ Scaled physical model to assess recovery potential

✓ Numerical simulation to predict reservoir performance

✓ Field trials

This project is part of SRC's Multiclient Petroleum Research Program. To find out more, contact

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Process Development

SRC Pipeline Centre

Before mining or petroleum companies commit substantial investment to pipeline projects, they often seek full-scale physical modelling of the complex pipe flow behaviour of their slurries, crudes, or other fluid mixtures. SRC's Pipeline Centre provides necessary experimental data to these industries in Canada and elsewhere, helping them to design effective pipeline applications with confidence.

"We offer full-scale testing for most industrial pipelining applications"

We Study These Mixtures

- Coal slurries
- Metallurgical minerals slurries
- Oil sand ore and tailings mixtures
- Potash slurries
- Waxy crude oils
- Heavy crude oil/water mixtures for pipeline transport
- Crude oil, water, sand, and gas mixtures in horizontal wells

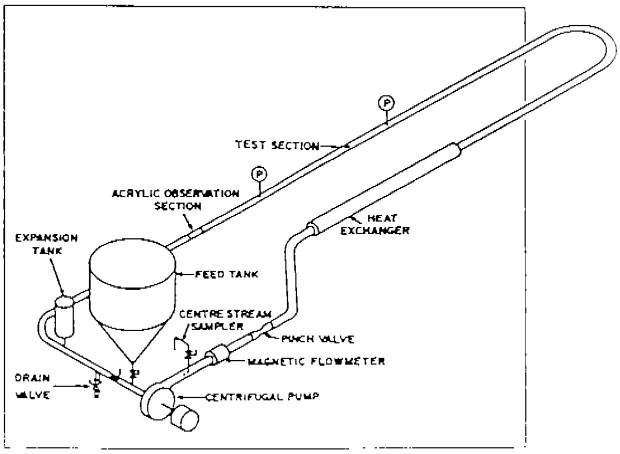
Background

The pipe flow behaviour of a two-phase or multi-phase mixture is usually much more complex than that of a single-phase fluid. The need for experimental studies providing realistic, reliable pipe flow data has long been recognized by the mining and petroleum industries. The latter produces mixtures containing as many as four phases (oil, water, gas and sand).

Pipeline Test Facility

SRC's pipeline research facility was established in 1969. With pipe diameters of 25, 50, 100, 150, 250, and 500 mm, the Centre is able to offer full-scale testing for most industrial pipelining applications. Actual pipe flow conditions are obtained in a laboratory environment where temperature, flowrate, and mixture composition can be controlled, and instrument performance can be optimized. During a typical pipe flow test, the following items of information would be collected:

- Mixture composition
- Particle or droplet size distribution
- Pump performance (rotational speed, head rise, efficiency)
- Pipeline frictional pressure gradient
- Density and velocity distributions for the mixture in the pipe



SRC has experimental flow loops with pipe diameters ranging from 25 to 500 mm

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Process Development

Support Services

SRC's Shops and Facilities personnel are experienced in the construction of pipeline test loops and specialized pipeline instrumentation. Clifton A. Shook, Principal, Shook Consulting, is the scientific advisor to SRC's Pipeline Centre. He has 40 years of experience in applying the principles of fluid mechanics to the flow of mixtures in pipelines.

SRC's Pipeline Centre performs work for multiple- or single-client contracts, and contributes significantly to projects in SRC's Multiclient Petroleum Research Program. To find out more, contact

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Process Development

Biofilm Reactor Technology for Waste Water Treatment

Biofilm reactor technology is a cost-effective, flexible method of treating organically contaminated waste waters. The Saskatchewan Research Council, under agreement with the University of Saskatchewan, is developing this technology for industrial application. SRC is the first to demonstrate the reduction of oil and grease in synthetic feeds with this reactor, which has also successfully degraded phenols.

"Oil and greases are successfully degraded by bacterial action"

The Reactor

The biofilm reactor consists of a high-density film of a specific bacteria adhering to a packing within a column. In the operation of this reactor, the waste water flows down over the packing while air flows counter current. This design enjoys the following benefits.

- Large surface area of coated packing provides excellent contact between water and bacteria.
- Oxygen transfer to the bacteria is efficient.
- Organic compounds are actually degraded rather than air stripped.
- Residence time is reasonable.
- This compact system can be sized to suit the water treatment needs of a specific user, such as an oil production facility.

Extensive testing at the U of S has overcome problems with fouling and plugging that limited earlier biofilm reactors; SRC is integrating these improvements in its design.

Potential Applications

- Refineries
- Chemical plants
- Oilfield production facilities
- Water contaminated with organic compounds

SRC welcomes the involvement of clients desiring an effective, low-cost solution to their water treatment concerns.

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1999/2000 Thermal EOR Projects - SRC

Horizontal Well

Year 5 (last year) of the existing multiclient project developing synergistic horizontal well/steam applications for improved heavy oil recovery. In addition, work in developing a continuous or semi-continuous sand cleanout system for horizontal wells and investigating multiphase flow in horizontal wells.

Benefits: increased recovery, rate of production and profitability of steam enhanced oil recovery operations. Reduced operating cost associated with conventional horizontal wellbore cleanouts.

Estimated Product Budget = $340,000 *Participation Fee = $35,000*

Integrated TEOR

The Integrated Thermal Recovery project seeks the synergies of a fully integrated steam injection field project. This includes improvements in i) reservoir efficiency, ii) subsurface equipment and methods and iii) surface equipment and methods. It is already known that good heat management will improve the thermal efficiency of a steam injection process. Cogeneration is being used in California to produce both electric power and steam from a common fuel source. This provides electric power for the field operations, with the excess capacity sold to commercial/residential users. The steam, which is almost a by-product, is injected into the oil reservoir to improve recovery. Can this concept be expanded to include the latest technology in treating and field upgrading? Are there other areas that could be included to further improve the process? By combining key elements in the three areas listed above, we can investigate process synergies, develop linkages to bridge technical gaps, and integrate the identified processes for optimum resource development. The proposal will be prepared after consultation with potential industry participants.

Benefits: improve the thermal efficiency of steam injection, reduce steam requirements and cost, reduce fresh water demands and extensive water processing, reduce greenhouse gas emissions, improve the quality and price of the sales product, and insulate the project from energy price differentials.

Estimated Product Budget = $130,000 *Participation Fee = $10,000*

Air Injection

This project has two goals:

1) Screen all Ordovician pools in southeastern Saskatchewan to determine whether air injection is a technically feasible oil recovery process.

Air injection is already an economically proven means to recover additional oil after primary depletion of deep, light-oil reservoirs. This has been shown best in North and South Dakota, where the Williston Basin is deepest and therefore the most favourable for this process. In the past few years, several deep light-oil reservoirs have been discovered in the Ordovician formations on the Saskatchewan side of the basin. On first glance, these reservoirs are potential air injection candidates; a proper screening study is needed.

2) Determine whether CO_2 generated by oxygen injection can economically compete with pipelined CO_2 for enhanced oil recovery.

The second objective stems from the fact that oxygen injection into an oil formation produces nearly pure CO_2 inside the reservoir. CO_2 flooding is now accepted as a technically viable and potentially profitable EOR process for the less-deep (mostly Mississippian) oil pools of southeastern Saskatchewan. The on-site separation and injection of pure oxygen may be a more economic alternative to the pipelining and purchase of CO_2.

Benefits: a cost effective enhanced oil recovery process for the deep Ordovician formations in south east Saskatchewan and an alternate and more cost effective method (compared to pipelining CO_2) of carbon dioxide enhanced oil recovery for the light and medium reservoirs in south east Saskatchewan.

Estimated Project Budget = $45,000 *Participation Fee = $5,000*

1999/2000 Production Operations Projects - SRC

EEOR	Emulsions EOR - Develop a non-thermal, cost effective, in-situ (reservoir), heavy oil emulsification process that will increase oil recovery and extend the life of producing fields. Application will likely be in situations where other, more expensive technologies are not applicable and possibly as an addition to (or in place of) water flooding. Laboratory testing continues to show potential and a field test at an early stage of development successfully produced oil from a reservoir that had an irreducible oil saturation. *Estimated Project Budget = $210,000* *Participation Fee = $15,000*
Fine Solids	Determine the full impact of the fine solids produced in conjunction with oil and water phases on the petroleum industry, including producers, pipeliners and upgraders. The fine solids problem can be more completely appreciated through identification and characterization. Then the potential of commercially available removal processes can be thoroughly investigated. In the next phase it is our intent to proceed with field testing and to develop a solids removal strategy. Such a strategy will reduce operating costs by reducing interface layers in treating vessels, reducing slop oil volumes, and improving the quality of refined products. *Estimated Project Budget = $120,000* *Participation Fee = $10,000*
Membrane	Investigate the potential of a newly developed oleophilic membrane for separating combined oil and water phases. The system reportedly works well with light crudes. If similar performance can be obtained with heavy crudes, pretreating with a membrane could improve conventional battery performance by increasing the throughput or reducing residence time, thereby reducing operating costs and the capital costs associated with upgrades and new equipment. *Estimated Project Budget = $80,000* *Participation Fee = $10,000*
Microwave	Investigate two separate and distinct applications of microwave energy: oil and water separation and crude oil upgrading. Previous testing with a single frequency microwave showed the equipment was capable of efficient emulsion heating. However, it did not disrupt the oil/water interface, allow coalescence, or enhance separation of a produced emulsion. The same equipment, when used in conjunction with additives, was able to reduce the level of sulphur in a crude oil but was not able to "upgrade" the oil on a bulk basis. Testing a range of frequencies with special variable-frequency equipment will test the idea that microwave treatment will advance these two applications. A separation procedure, when developed, would reduce residence time in a conventional treater allowing higher throughput and reduced per barrel operating costs. It would also reduce capital costs by allowing more efficient treating in smaller vessels. An upgrading procedure could lead to design of a small scale field upgrading process, providing a value added oil product for the producer. *Estimated Project Budget = $80,000* *Participation Fee = $10,000*

1999/2000 Gas/Chemical EOR Projects - SRC

MPC - M/C Methane Pressure Cycling for Heavy Oil — The goal is to develop a non-thermal, cost-effective EOR process for thin-pay heavy oil reservoirs. The technology uses methane pressure cycling in combination with infill horizontal production wells. Encouraging results have been obtained by studying the Senlac (2,000 mPa•s oil) and Cactus Lake North (6,000 mPa•s oil) fields. The promise of substantial oil recovery from these reservoirs has been indicated by our laboratory testing. This year we will investigate the potential of the process for the Plover Lake reservoir (4,000 mPa•s oil) in the Kindersley area. The proposed one-year study will optimize the process to achieve high recovery factors while maintaining economic operations. We are expecting a field test from the project participants.

Estimated Project Budget = $180,000 *Participation Fee = $30,000*

Green EOR II Determine the synergies, benefits, and penalties between greenhouse gas storage and EOR applications when injecting greenhouse gases in oil-bearing reservoirs. This year the project will put more emphasis on bottomwater reservoirs and will investigate the EOR effects of CO_2 contaminants such as H_2S and SO_2. Numerical simulations will be run optimizing the EOR and gas storage processes. This project is a continuation of last year's work that was funded by the Petroleum Technology Research Centre (PTRC). This year industry is invited to participate.

Estimated Project Budget = $200,000 *Participation Fee = $10,000*

Chemical EOR The purpose is to study the technical feasibility of alkaline/ surfactant/polymer (ASP) flooding in southwest Saskatchewan's medium oil reservoirs. The ASP flood technique uses alkali to replace most of the surfactant employed in conventional chemical (micellar/polymer) flooding, thus significantly reducing the cost of chemicals. The objectives are to: (a) determine whether southwest Saskatchewan's medium oil reservoirs are good candidates for ASP flooding, (b) determine whether and how a synergistic enhancement can be obtained in an ASP flood, and (c) establish what kind of ASP system is effective for the reservoirs of the region. The work will include characterization of the reservoirs and fluids in the region, measurements of interfacial tension between oil and formation brine, comprehensive investigation of the interaction between the ASP system and the crude oil and formation water, and coreflood tests. From this study, the following questions will be answered:

1) Based on the reservoir conditions, what is the percentage of reservoirs in southwest Saskatchewan to which the ASP flooding technique can be applied?

2) Are the oils in the region suitable for chemical flooding? Is there potential for applying alkali to react with the crudes of the region to form surface active agents?

3) Can one obtain an ultra-low interfacial tension between the surfactant solution and a typical crude oil in southwest Saskatchewan? Can alkali replace the surfactant for reducing oil/water interfacial tension for the region's oil?

4) Compared to the oil recovery of the waterflood, what are the incremental oil recoveries of polymer, surfactant/polymer, and alkaline/surfactant/polymer floods?

Estimated Project Budget = $120,000 *Participation Fee = $15,000*

GPC - SW Given the demonstrated potential of SRC's methane pressure cycling process for heavy oil reservoirs, the purpose here is to establish the feasibility of a process variation for southwest Saskatchewan medium oils. The use of carbon dioxide as a viscosity-reducing agent would be incorporated into a vertical production well gas pressure cycling scheme. This design is expected to increase rates of production and reduce injected gas requirements. The objectives are to:

a) assemble the necessary data, including relative permeabilities, for conducting numerical simulations of carbon-dioxide-containing pressure cycles of southwestern Saskatchewan medium oils,

b) establish a few cycles of the baseline case of methane pressure cycling with a vertical production well for a medium oil, and

c) do an initial evaluation of the consequences of injecting: an initial slug of carbon dioxide, per cycle carbon dioxide slugs, and mixed gas inputs (co-injection of carbon dioxide and methane) to pressure cycling of a medium oil reservoir.

The feasibility of this application will be established by numerical simulation.

Estimated Project Budget = $42,000 *Participation Fee = $20,000*

1999-2000 Process Engineering Projects - SRC

Supercritical H_2O

Heavy Oil Upgrading Using Supercritical Water - Develop a simple, rapid upgrading process suitable for small-scale applications. This technology reacts oil with water under high-temperature and high-pressure conditions to make a product that will meet pipeline viscosity specifications. We have demonstrated that heavy oil viscosity can be reduced with this technology in a relatively short period of time (less than 30 minutes). Another benefit of this conversion method is the low gas yield - this means more liquid product. This year we will be working to improve sulphur removal and density reduction. A method for generating hydrogen in the reactor was developed last year. Increasing hydrogen transfer will reduce sulphur and density. The proposed one-year study will optimize the process further prepare the required information for a field test.

Estimated Project Budget = $140,000   *Participation Fee = $30,000*

Ionic Liquids

Using Ionic Liquids to Upgrade Heavy Oil - Develop an upgrading process that uses ionic liquids (molten salts) to promote the conversion of high boiling point liquids. We have demonstrated that molten salt mixtures at room temperature and pressure will cause heavy oil molecules to crack and form a lower boiling range hydrocarbons. Ionic liquids can also be used to cause hydrogenation reactions. This is a very simple, novel process that has the potential to be applied in a variety of situations. The process will require minimum capital investment and will have low operating costs. Heavy oil cracking at room temperature takes a long period of time (about 6 days). We will be working this year to find conditions that will promote reactions in a much shorter period. Another task will be to find a method to separate the converted hydrocarbons from the ionic mixture without neutralizing the ionic liquids.

Estimated Project Budget = $210,000   *Participation Fee = $30,000*

Intelligent Systems

Artificial Intelligent System Development for Oil–Water Separation Processes - The purpose of this work is to develop an intelligent software system that will provide better control of the oil–water separation process. Current control of this process is far from optimum, current control strategies cannot deal efficiently with changing composition and flow rates to the process units. An intelligent system will be able to make decisions based on human knowledge and physical measurements. Instead of requiring an operator to make frequent adjustments, the software will make most of the decisions. This will reduce energy requirements, chemical addition, and the amount of oil that has to be treated again to meet pipeline specifications. SRC expects to apply to PRECARN (a federally funded organization that supports the application of intelligent systems in industry) for some financial support. A commercial system is expected to be tested in the second year of this project.

Estimated Project Budget = $300,000 *Participation Fee = $30,000*

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