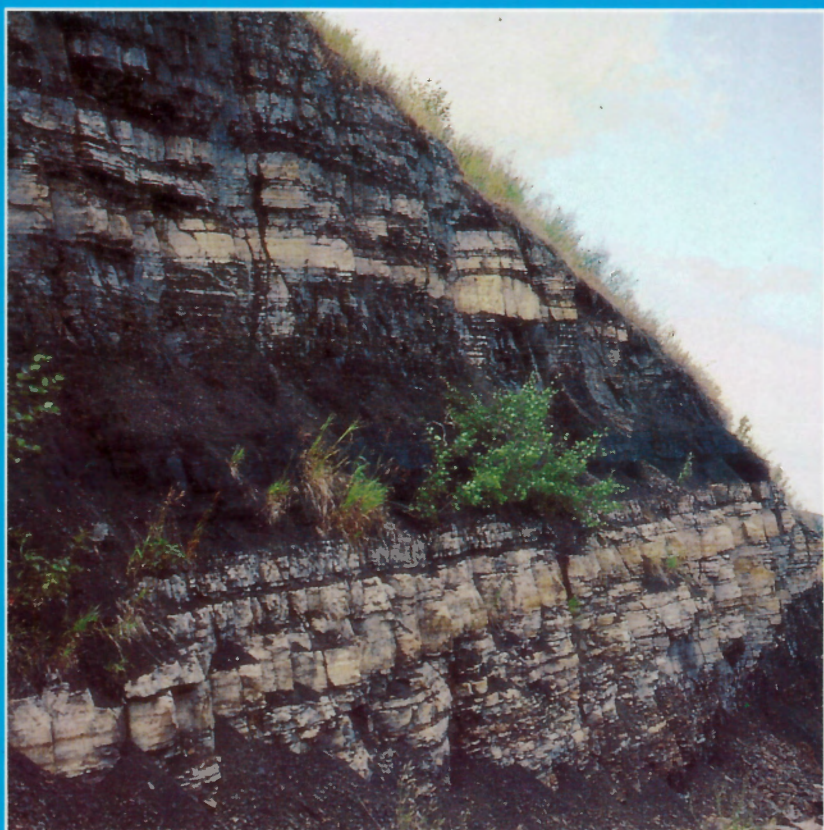
GEOLOGICAL SURVEY OF CANADA
BULLETIN 517

MANNVILLE GAS RESOURCES OF THE WESTERN CANADA SEDIMENTARY BASIN

W.J. Warters, D.J. Cant, H.P. Tzeng, and P.J. Lee



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Nonmarine sandstones and shales of the Gething Formation, W.A.C. Bennett dam, northeastern British Columbia. Photographed by Doug Cant.

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PREFACE

Appraisals of oil and gas resources in the major sedimentary basins of Canada are undertaken on a continuing basis by Natural Resources Canada. These appraisals provide objective estimates of Canada's oil and gas resources, generate data for forecasting future supply, and serve as a basis for efficient resource management and planning.

Natural gas is playing an increasingly important role in the petroleum industry. This has been demonstrated in the last few years with the building of new production gathering facilities and transportation infrastructure. The creation of new domestic and export markets for western Canadian natural gas is resulting in an increased demand for what has become the fuel of choice for many applications. Thus, the systematic estimation of both the amount of undiscovered natural gas and the economic conditions under which it may be extracted and sold continues to be an important priority for Natural Resources Canada.

This study decribes the petroleum geology of the Mannville Group exploration plays, and provides an assessment of remaining natural gas potential. The geological analysis and resource assessment were undertaken by the Calgary office of the Geological Survey of Canada. The estimates of potential, expressed in probabilistic terms, were prepared using statistical techniques developed at GSC Calgary.

This report is part of a series of publications on the natural gas resources of western Canada. The information in these reports will provide a regional synthesis of petroleum geology and will assist in evaluating opportunities for exploration and development in western Canada. The studies also further the understanding of petroleum geology, showing progress in methodologies of resource assessment and economic evaluation.

M.D. Everell
Assistant Deputy Minister
Earth Sciences Sector

PRÉFACE

Le personnel du ministère des Ressources naturelles du Canada produit régulièrement des évaluations des ressources en pétrole et en gaz des principaux bassins sédimentaires du Canada; celles-ci donnent la possibilité d'en arriver à des estimations objectives des ressources en pétrole et en gaz du Canada, sont à l'origine de données qui permettent de prévoir l'offre future et sont fondamentales en matière de gestion efficace des ressources.

Le gaz naturel joue un rôle grandissant dans l'industrie pétrolière. Ce fait s'est avéré au cours des toutes dernières années, comme en témoigne la construction de nouvelles installations de collecte et d'infrastructures de transport. La création de nouveaux marchés pour le gaz naturel de l'Ouest canadien, tant au pays qu'à l'étranger, se traduit par une demande croissante pour ce combustible, devenu le choix par excellence dans le cas de nombreuses applications. Ainsi, l'évaluation systématique de la quantité de gaz naturel non découvert, tout comme l'analyse des conditions économiques permettant l'extraction et la vente de ce combustible, sont deux aspects qui continuent d'être prioritaires pour Ressources naturelles Canada.

Le présent document contient une description de la géologie des zones gazéifères du Groupe de Mannville et une estimation de son potentiel en gaz naturel (ressources non découvertes). L'analyse géologique et l'évaluation des ressources ont été réalisées par le personnel du bureau de la Commission géologique du Canada (CGC) à Calgary. L'estimation du potentiel, exprimée en termes probabilistes, a été préparée en utilisant les techniques statistiques mises au point à ce bureau.

Ce document, un bulletin de la CGC, fait partie d'une série de publications sur les ressources en gaz naturel de l'Ouest canadien qui, une fois complétée, constituera une synthèse régionale de la géologie pétrolière de ce coin de pays et aidera à y déterminer les possibilités d'investissement en matière d'exploration et de mise en valeur des hydrocarbures. Ces publications contribuent également à l'avancement des connaissances en géologie pétrolière, en faisant état des progrès accomplis dans les méthodes d'estimation des ressources et d'évaluation économique.

M.D. Everell
Sous-ministre adjoint
Secteur des sciences de la Terre

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MANNVILLE GAS RESOURCES OF THE WESTERN CANADA SEDIMENTARY BASIN

Abstract

The Mannville Group contains 1 504 655 x 10^6 m^3 discovered gas-in-place, which represents almost one-quarter of the total discovered gas resources of the Western Canada Sedimentary Basin. The assessment of the undiscovered, or potential, gas resources in the Mannville Group involved outlining the principle geological plays in the Mannville Group and statistically evaluating the potential gas resources of each play. Based on this study an additional 957 491 x 10^6 m^3 gas-in-place exists within the Mannville Group in the Western Canada Sedimentary Basin. Northwest Alberta and northeast British Columbia have the highest potential gas resources (199 634 x 10^6 m^3 gas-in-place) and within this area the Cadomin Formation play is estimated to have the highest potential gas resources (100 010 x 10^6 m^3 gas-in-place) and the largest undiscovered pool (10 856 x 10^6 m^3 gas-in-place).

Résumé

Un volume de 1 504 655 x 10^6 m^3 de gaz en place est associé au Groupe de Mannville, ce qui représente presque le quart de toutes les ressources en gaz découvertes dans le Bassin sédimentaire de l'Ouest du Canada. Pour évaluer les ressources en gaz non découvertes (ou le potentiel) dans le Groupe de Mannville, il a falllu délimiter les principales zones gazéifères en fonction de la géologie de cette unité de roches et déterminer le potentiel en gaz de chaque zone à l'aide de techniques statistiques. Selon la présente étude, il existe un volume supplémentaire de 957 491 x 10^6 m^3 de gaz en place dans le Groupe de Mannville du Bassin sédimentaire de l'Ouest du Canada. C'est le secteur d'exploration du nord-ouest de l'Alberta et du nord-est de la Colombie-Britannique qui offre le potentiel prévu le plus élevé (199 634 x 10^6 m^3 de gaz en place); et dans ce secteur, la zone gazéifère de Cadomin serait celle au potentiel prévu le plus élevé (100 010 x 10^6 m^3 de gaz en place) et celle qui contiendrait le gisement non découvert le plus volumineux (10 856 x 10^6 m^3 de gaz en place).

Summary

This report presents the results of the Mannville Group gas resource assessment in the Western Canada Sedimentary Basin (WCSB). Resource Assessment Procedure and the methodology of PETRIMES, the statistical evaluation method employed in this study are explained. The regional geology of the Mannville Group in the Western Canada Sedimentary Basin is described, as is the basis on which the plays were defined for the assessment. Detailed descriptions of the plays and the play resource assessment results are presented.

More than thirteen thousand gas pools have been discovered in the Mannville Group (as of December 1990), with total discovered gas resources of 1 504 655 x 10^6 m^3 gas-in-place. The Mannville Group contains 23.6 per cent of the total gas resources discovered in the Western Canada Sedimentary Basin. The Western Canada Sedimentary Basin was divided into six exploration areas for the gas assessment of the Mannville and each of these areas was subdivided stratigraphically, resulting in a total of 17 plays. The undiscovered potential gas resources for each play were assessed using the discovery process models of PETRIMES.

Once a play is defined, all the wells and pools within the formation(s) identified in the play definition are retrieved from the PETRIMES well and pool database. The pool lists provide the pool sizes and discovery dates for each play; these are used to produce a discovery sequence. These are the basic input data required by the discovery process model for estimating the undiscovered or potential gas resources.

The expected potential gas resources for the Mannville Group are 957 491 x 10^6 m^3 gas-in-place. Based on this estimate, 39 per cent of the total gas resources of the Mannville Group remains to be discovered. Northwest Alberta and northeast British Columbia have the highest gas potential (199 634 x 10^6 m^3 gas-in-place). The Cadomin play of northwest Alberta and northeast British Columbia has the largest expected potential gas resources (100 010 x 10^6 m^3 gas-in-place) and the largest undiscovered pool (10 856 x 10^6 m^3 gas-in-place) within the Mannville Group.

Sommaire

Le présent bulletin fait état des résultats de l'évaluation des ressources en gaz dans le Groupe de Mannville du Bassin sédimentaire de l'Ouest du Canada (BSOC). Toutes les étapes d'évaluation des ressources et le PETRIMES (la méthode statistique utilisée dans la présente publication) sont d'abord expliqués. Suit une description de la géologie régionale du Groupe de Mannville, une unité du Bassin sédimentaire de l'Ouest du Canada, laquelle description sert de base à la définition des zones gazéifères aux fins de l'évaluation. Des descriptions détaillées des zones gazéifères ainsi que les résultats d'évaluation des ressources contenues dans ces zones forment le corps du bulletin.

Au mois de décembre 1990, plus de treize mille gisements de gaz représentant des ressources découvertes totales de 1 504 655 x 10^6 m^3 de gaz en place avaient été identifiées dans le Groupe de Mannville. Cette unité contient donc 23,6 % du total des ressources en gaz découvertes dans le Bassin sédimentaire de l'Ouest du Canada. Celui-ci a été divisé en six grands secteurs d'exploration aux fins de l'évaluation des ressources en gaz du Groupe de Mannville; chacun d'eux a ensuite été subdivisé selon la stratigraphie, pour en arriver à un total de six-sept zones gazéifères. Les ressources non découvertes (potentiel) de chaque zone gazéifère ont été établies au moyen des modèles de processus de découverte du PETRIMES.

Lorsqu'une zone gazéifère a été délimitée, tous les puits et gisements de la ou des formation(s) identifiée(s) dans la définition de la zone sont extraits de la base de données du PETRIMES. Les listes des gisements indiquent le volume et l'année de découverte de chacun d'eux et ce, pour chaque zone gazéifère; ces données servent à produire une séquence de découverte. Elles sont le fondement du modèle de processus de découverte qui permettra d'estimer les ressources en gaz non découvertes ou le potentiel d'une zone.

Le ressources de gaz en place qu'on prévoit trouver dans le Groupe de Mannville (potentiel prévu) ont un volume de 957 491 x 10^6 m^3. Selon cette estimation, 39 % des ressources totales en gaz du Groupe de Mannville n'ont pas encore été découvertes. C'est le secteur d'exploration du nord-ouest de l'Alberta et du nord-est de la Colombie-Britannique qui offre le potentiel prévu le plus élevé (199 634 x 10^6 m^3 de gaz en place); et dans ce secteur, la zone gazéifère de Cadomin serait celle au potentiel prévu le plus élevé (100 010 x 10^6 m^3 de gaz en place) et celle qui contiendrait le gisement non découvert le plus volumineux (10 856 x 10^6 m^3 de gaz en place) du Groupe de Mannville.

INTRODUCTION

Purpose

This report documents a detailed analysis of conventional natural gas resources estimated to be contained in the Mannville Group and stratigraphic equivalents, in the Western Canada Sedimentary Basin. It is part of a series of reports dealing with conventional gas resources of the Western Canada Sedimentary Basin. Estimates of regional resource potential have been prepared periodically by the Geological Survey of Canada (i.e., Dixon et al., 1994; Podruski et al., 1988; Wade et al., 1989; Sinclair et al., 1992; Reinson et al., 1993; Bird et al., 1994), using systematic geological basinal analysis and statistical resource evaluation methods. The initial computer-based statistical evaluation methods were developed within the Geological Survey of Canada by Lee and Wang (1983a, b, 1984, 1985, 1986), and subsequently refined into the present PETRIMES system (Lee and Wang, 1990; Lee and Tzeng, 1993), which is employed here for estimating resource potential of established plays.

Because of the enormity of the well and pool database, the number of plays, and the geological and economic complexities associated with those plays, the assessment of the natural gas resource potential of western Canada is divided into eight major play groups. The play groups are divided on the basis of geological criteria, primarily major stratigraphic time-rock units or structural/tectonic provinces, each having a distinct set of geological factors that controls the size, distribution, and type of hydrocarbon play or reservoir. The major play groups for the Western Canada Gas Assessment project are the Devonian, Permo-Carboniferous, Triassic, Jurassic, Deformed Belt, Mannville Group, Colorado Group, and post-Colorado Group.

The Mannville Group in the Western Canada Sedimentary Basin contains 1 504 655 x 10^6 m^3 gas-in-place, which represents 23.6 per cent of the total gas resources of the basin (Fig. 1). For the Mannville assessment, the Western Canada Sedimentary Basin was divided into six exploration areas: 1) northwest Alberta and northeast British Columbia; 2) Athabasca; 3) Lloydminster; 4) central Alberta; 5) southern Alberta, and 6) Saskatchewan (Fig. 2). Each area was further subdivided, based on the stratigraphy of the Mannville Group, resulting in a total of seventeen plays.

The objectives of this study are three-fold: 1) to estimate the total amount of gas that might exist in the Mannville Group, regardless of whether all of it will ever be discovered or economically exploitable; 2) to outline the principal gas plays in the Mannville Group in a manner that will enable industry to evaluate the potential of individual exploration prospects, and 3) to provide the necessary geological and resource potential information to allow industry and government agencies to undertake economic viability studies with respect to exploration, producibility, and ultimate marketability.

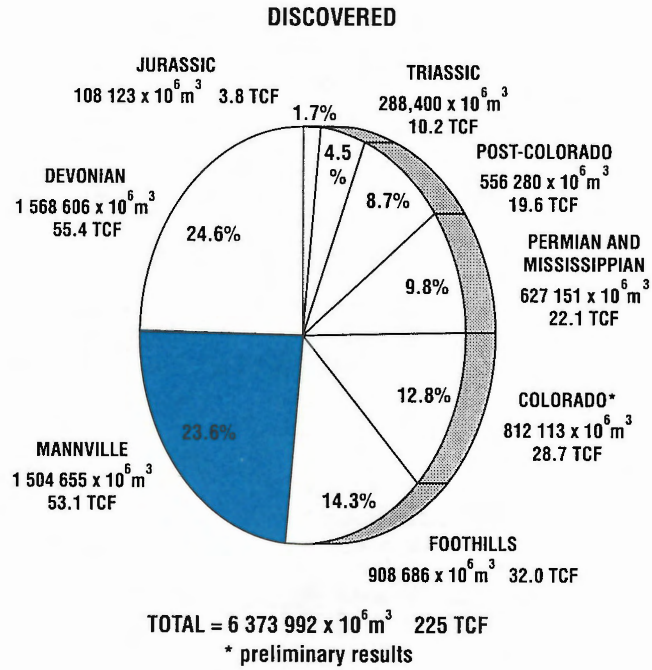


Figure 1. *Distribution of discovered gas resources of the Western Canada Sedimentary Basin by geological system. (Based on data from the Alberta Energy Resources Conservation Board, 1990, British Columbia of Energy, Mines and Petroleum Resources, 1991, and Saskatchewan Energy and Mines, 1989).*

Terminology

The term *natural gas*, as used in this report, is defined as any gas (at standard pressure and temperature of 14.65 psia and 60°F (101.325 kPa and 15°C, respectively) of natural origin, producible from a borehole, and composed primarily of hydrocarbon molecules (Energy Resources Conservation Board, 1991).

Raw gas is unprocessed natural gas, containing methane, inert and acid gases, impurities, and other hydrocarbons, some of which may be recoverable as liquids. *Sales gas* or marketable gas is natural gas that

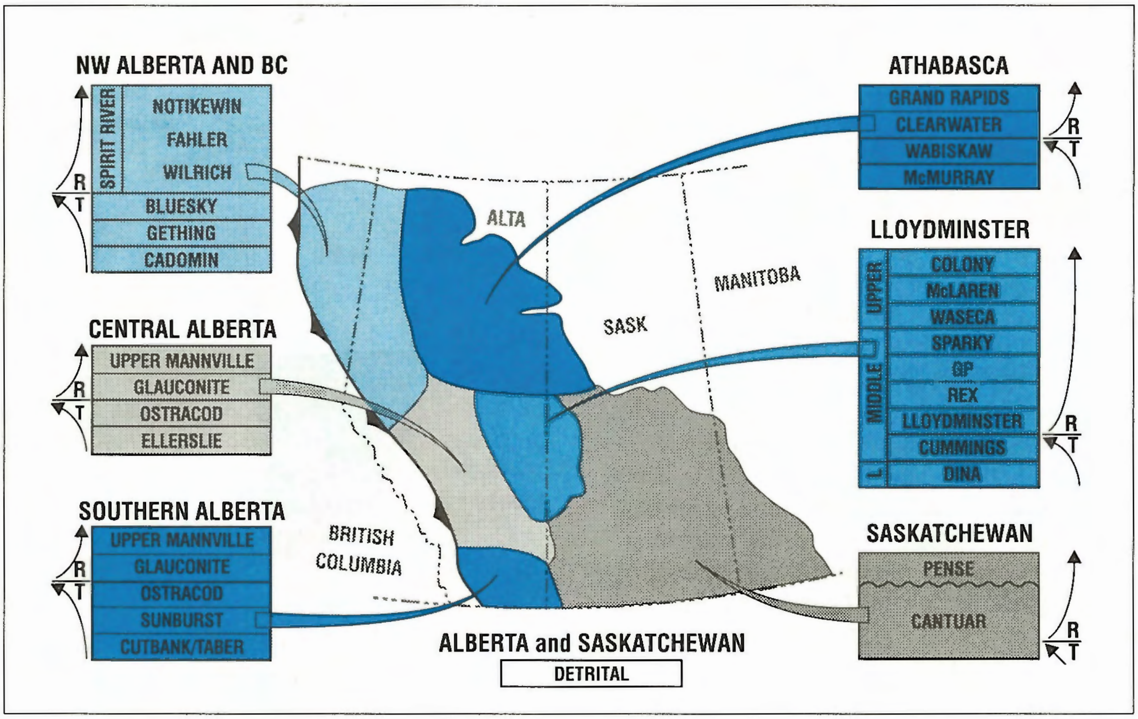


Figure 2. *Regional distribution of the Mannville Group plays in the Western Canada Sedimentary Basin. T and R indicate the transgressive and regressive successions in each area.*

meets specifications for end use, usually requiring processing to remove acid gases, impurities, and liquid components. *Nonassociated gas* is natural gas that is not in contact with crude oil in a reservoir. *Associated gas* is natural gas that occurs in crude oil reservoirs as free gas. *Solution gas* is natural gas that is dissolved in crude oil under reservoir conditions.

In making the estimates of potential natural gas in the Mannville, it was not practical to separate nonassociated, associated, and solution gas resources. Where designated as discrete entities within a pool, solution and associated gas volumes were added together. Pools, as discussed in this report, may be composed of nonassociated gas (NA), or of various combinations of nonassociated, associated (A), and solution gas (S). The estimates of gas reported here reflect only total natural gas resources. However, within the description of each mature play the principal mode of gas occurrence is indicated in the pool-rank table.

The terms *resource*, *reserves,* and *potential*, as defined by the Geological Survey of Canada (Podruski et al., 1988), are retained in this report. *Resource* is defined as all hydrocarbon accumulations known or inferred to exist and includes both discovered and undiscovered volumes. *Reserves* are that portion of the resource that has been discovered. The term *potential* describes the portion of the resource that is inferred to exist but as yet is undiscovered. The terms potential and undiscovered resources are synonyms and may be used interchangeably.

The expression *established reserve* is used to describe those reserves which, under given economic conditions and within a specified time frame are *recoverable* with a high degree of confidence from known reservoirs. The expression *gas-in-place* is used to represent the gross volume of gas calculated, or interpreted, to exist in a reservoir before any gas has been produced.

The terms *field*, *play*, *pool*, and *prospect* have the following designated meanings in this report. Within this study, a *field* is used to designate an area that produces gas, without stratigraphic interval restrictions. A *pool* is a discovered accumulation of gas, typically within a single stratigraphic interval, that is hydraulically separate from any other gas accumulation. Any number of pools can exist within a field. A *strike area* refers to a well that is producing gas but has not been assigned to a specific pool or field (Energy Resources Conservation Board, 1991). In British Columbia the term *other area* is synonymous with strike area. A *prospect* is an untested exploration target, usually within a single stratigraphic interval, that may contain natural gas. A *play* consists of a family of pools and/or prospects that share a common history of hydrocarbon generation, migration, reservoir development, and trap configuration.

Plays are grouped into two categories: *established plays* (those that are demonstrated to exist by virtue of discovered pools with established reserves) and *conceptual plays* (those that do not yet have discoveries or reserves but which geological analysis indicates may exist). Established plays are grouped into *mature* and *immature* plays on the basis of adequacy of the play data for the statistical discovery process analysis. *Mature* plays are those plays in which the profile of the discovery sequence is adequate to be analyzed by the discovery process models, as defined by the *PETRIMES* assessment procedure (discussed later). *Immature* plays are those in which the number of pools (and therefore the discovery sequence) is inadequate for application of the discovery process models.

Method and contents

The assessment of Mannville gas resources has two essential components: geological analysis and statistical analysis. The geological analysis is the fundamental component, involving characterization of the exploration play. Pools and prospects within a play form a natural geological population that can be delimited areally. Once the plays are defined, numerical resource assessments can be undertaken using several methods, using pool and prospect data from each specific play.

The analysis of Mannville gas potential involved delineation and systematic evaluation of 17 established plays. Sixteen plays were classified as mature, while only one was considered immature. The report contains a brief description of all established plays, including play definition, geology, exploration history, and numerically estimated resource potential, with supporting figures. Each established play is designated by geographic area and by geological unit. Conceptual plays are treated separately, primarily in a descriptive manner, but the total potential of the conceptual plays is estimated using the 16 mature plays as the "pool" database.

The pool and well data used in the assessments are based on data sets of the provincial agencies of Alberta (Energy Resources and Conservation Board, 1990), British Columbia (Ministry of Energy, Mines, and Petroleum Resources of British Columbia, 1991) and Saskatchewan (Saskatchewan Energy and Mines, 1990).

RESOURCE ASSESSMENT PROCEDURE

Numerous methods exist for estimating the quantity of hydrocarbons that may exist in a play, region, or basin. The method used depends on the nature and amount of data available for the assessor to consider. Haun (1975), Grenon (1979), White and Gehman (1979), Roy (1979), Roadifer (1979), Drew et al. (1980), Masters (1984), and Rice (1986), have described approaches currently in use. For the assessment of the Mannville gas resources of the Western Canada Sedimentary Basin, PETRIMES (Lee and Wang 1990, Lee and Tzeng, 1993) was employed.

The resource assessment procedure using PETRIMES is best described by outlining the various steps that were undertaken during analysis of the Mannville gas plays, and by illustrating one of the mature plays, the Athabasca-McMurray play, as an example.

Play definition

The definition of play type and play area are the primary objectives of the basin analysis studies that precede the resource evaluation. The specific areal extent of the play is contained within a *play boundary* or *play polygon* (Fig. 3). The extent of the play boundary is governed by the distribution of pools within that play. By definition, pools in a specific play form a natural geological population that is characterized by one or more of the following: stratigraphic horizon, depositional model, structural style, type of trapping mechanism, geometry, or diagenesis.

Proper definition of the play type is vital so that it will correspond to a single statistical population, thus satisfying the statistical assumptions required for the valid operation of the evaluation models. A mixed population, resulting from an improper play definition, will adversely effect the quality of final resource estimates derived from the statistical evaluation.

Compilation of play data

Once a play is defined and the play boundary has been outlined as a closed polygon (Fig. 3), all the wells and pools within the stratigraphic unit identified in the play definition are retrieved from the PETRIMES well and pool database. The well and pool lists are then examined to ensure they are consistent with the play definition and play boundary. The pool lists

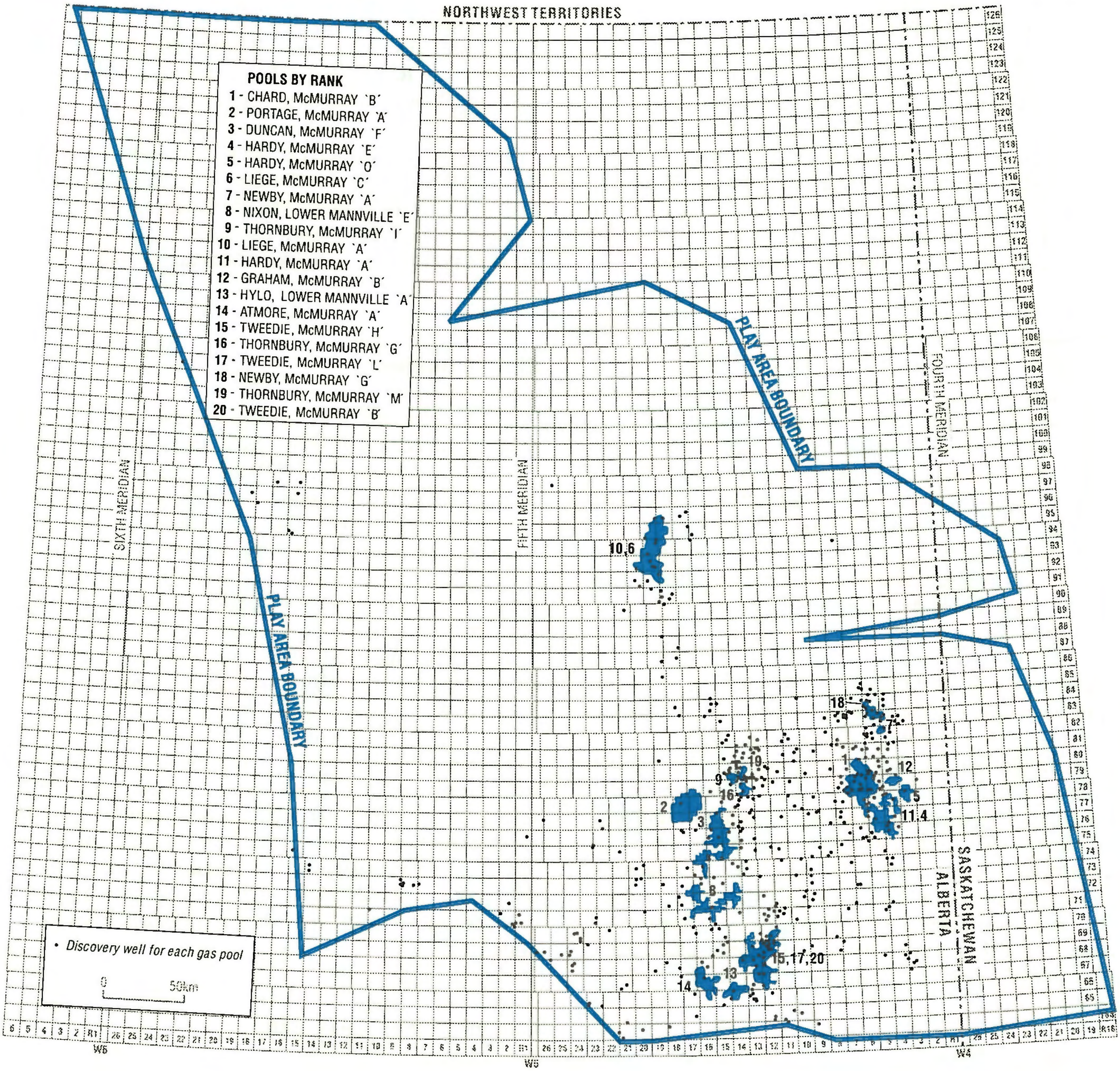


Figure 3. Play map: Athabasca–McMurray Formation play. Pools listed in Table 7.

provide the pool sizes and discovery dates for each play, which are used to produce an exploration discovery series (Fig. 4). These are the basic data required by the discovery process models for estimating the quantity of undiscovered petroleum resources.

Discovery process models

As an exploration program continues over time, pools are discovered, and these pools are samples from the underlying pool population of the play. However, the

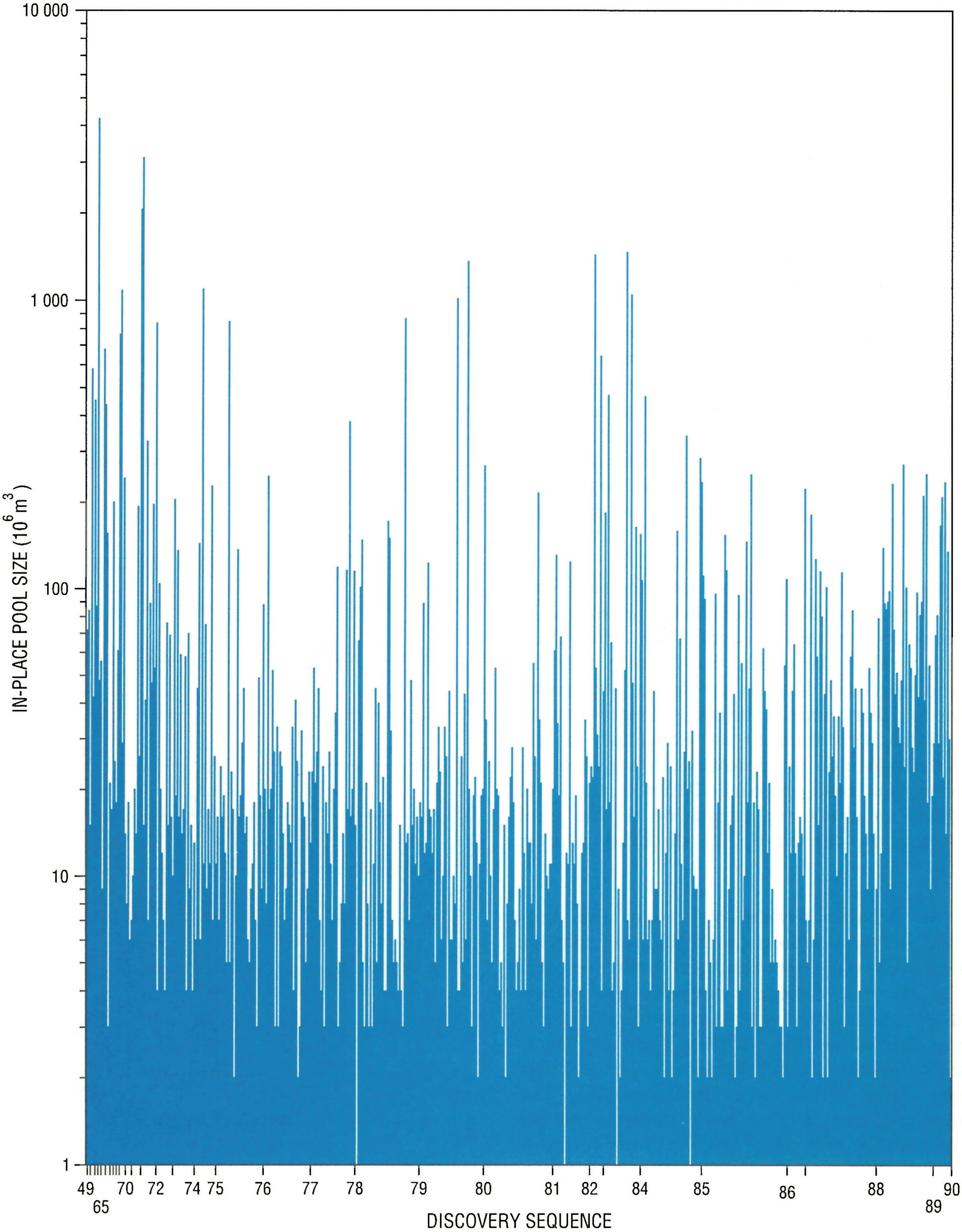


Figure 4. Discovery sequence: Athabasca–McMurray Formation play.

population of discovered pools is biased because explorationists tend to drill the best and therefore largest prospects first. This logical, but biased, nature of the sample prevents us from using standard statistical methods for estimating undiscovered petroleum resources.

The lognormal (or parametric) discovery process model was devised to account for this biased element within the sample. Kaufman et al. (1975) and Lee and Wang (1985) incorporated this biased element into a probabilistic model in order to adequately estimate the mean and variance of a given underlying natural geological population. Two assumptions are inherent in this model: 1) the probability of discovering a pool is proportional to its size, and 2) sampling occurs without replacement, that is, a pool will not be discovered twice. The first assumption is supported by plotting the discovery sequence in a time series. The second assumption is self-evident. The biased nature of the sample obtained from the exploration process contains information not only about the mean and variance of the pool-size population but also about the total number of pools within the play. A second method, the nonparametric discovery process model, adopts the same assumptions as the lognormal discovery process model except the lognormal assumption (Lee and Wang, 1990).

Both lognormal (or parametric) and nonparametric discovery process models were applied on all Mannville play data-sets. In most cases both estimation procedures yield similar results, but in some cases the parametric approach fails to provide a satisfactory result due to either numerical errors associated with the computational algorithm, or an inadequacy of the lognormal distribution in approximating the data set. In addition, the finite approach (Bickel et al., 1992) was applied to check the estimation of the total number of pools derived by the discovery process models.

For the Athabasca-McMurray play, the nonparametric discovery process model indicates that the total number of pools (discovered and undiscovered) is 1100 (Fig. 5). The empirical pool-size distribution derived by the model was approximated by a lognormal distribution (Fig. 6). These two components were used to estimate the individual pool sizes and play potentials (refer to the next two sections). The exploration efficiency, β value, is 0.6, implying that the pool size is not the only factor to control the discovery sequence.

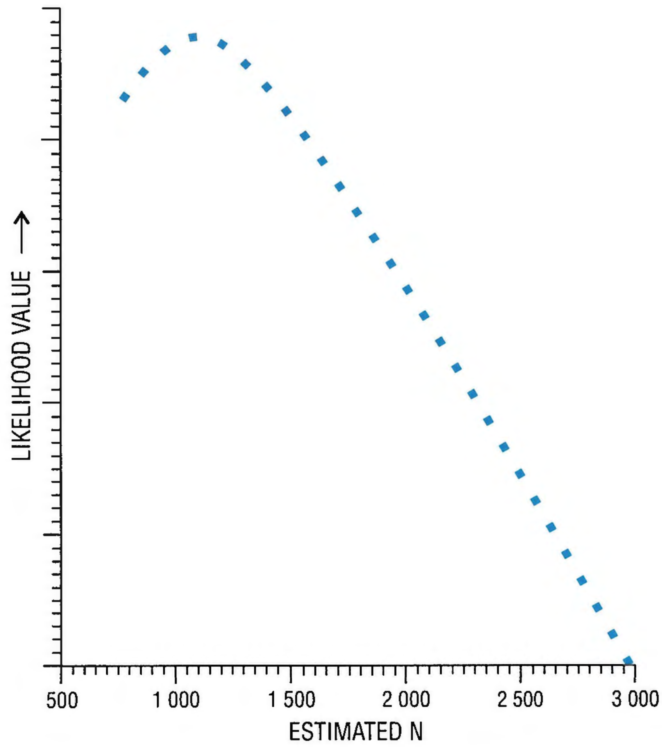


Figure 5. *Relation between the likelihood value versus estimated N.*

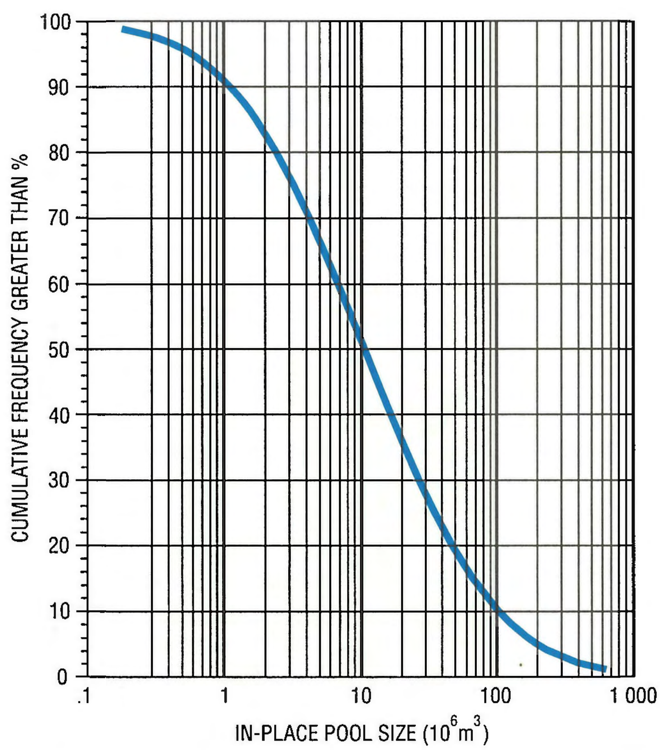


Figure 6. *Pool-size distribution: Athabasca–McMurray play.*

Individual pool-size distribution

The number of pools (1100) and the lognormal pool-size distribution were used to predict the distributions of the individual pool sizes. The distributions of the individual pool sizes are in the form of cumulative frequencies greater than percentage and can be represented in a graphical form by bars which indicate the range of possible sizes (Fig. 7a). The bars are arranged on the graph to represent an array of pools from the largest to the smallest. The graph plots individual pool size against pool rank. A bar with a frequency interval of 5 to 95 indicates that there is a 90 per cent chance that the pool will fall somewhere within the size range constrained by the interval.

After the individual pool sizes have been estimated, the sizes of discovered pools are matched to medians of the individual pool size distributions by PETRIMES. The matched (discovered) pools are indicated in graphical form by dots and the unmatched (undiscovered) pools by bars. The sizes of the undiscovered pools are further constrained by the fact that their size ranges cannot exceed, or be less than, any discovered (matched) pools that are ranked greater than the unmatched pool (Fig. 7b).

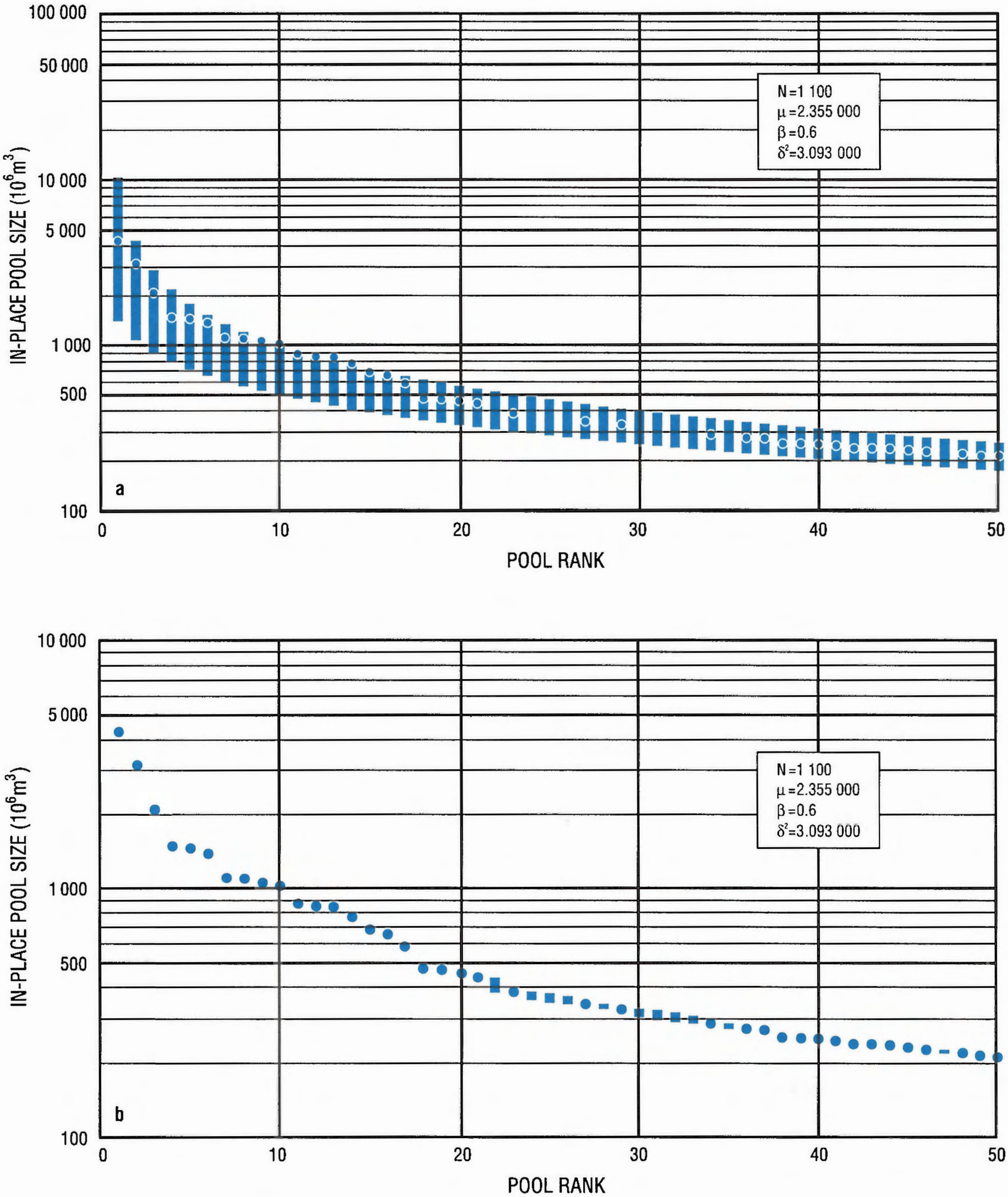


***Figure 7.** **a**) Pool-size-by-rank plot, and **b**) Pool-size-by-rank plot conditioned on the discovered pool sizes, for the Athabasca–McMurray play.*

Estimate of play potential

The play potential can be estimated from the total number of pools (N) and the pool-size distribution. Summation of the mean of all undiscovered pool sizes yields the mean of the play potential distribution, defined as the *expected potential.* The play potential can also be derived from conditions on the discovered resource of a play (Fig. 8), defined as the *probable potential.* The probable potential has a higher degree of uncertainty than the expected potential.

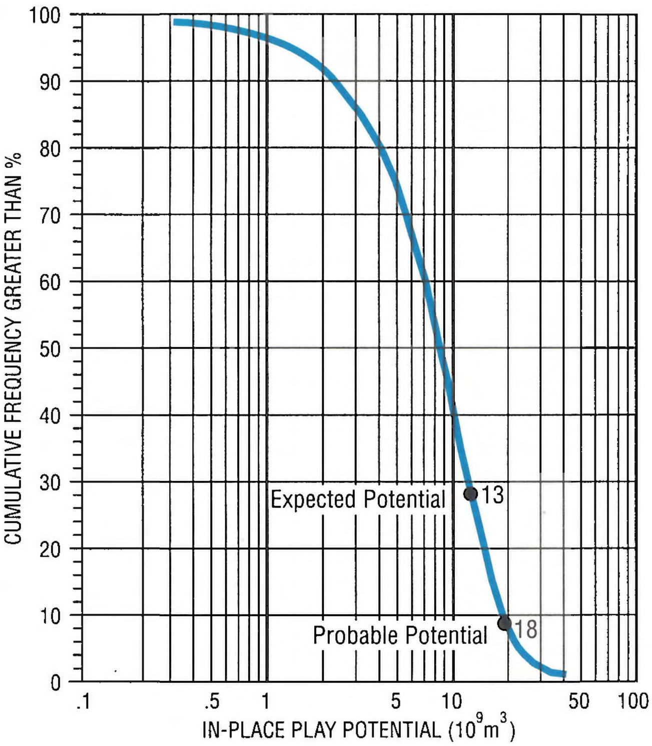


***Figure 8.** Play potential distribution of the Athabasca-McMurray play.*

The expected value of the potential is governed by an estimated range of values for each of the individual pool sizes and the assigned pool ranks. Both the range of individual pool sizes and the pool ranks are controlled by the quality of the discovered pool database. If the discovered pool sizes are incorrectly estimated, appreciated or depreciated, or if the rankings are altered, then the expected value of the potential will be altered. Provided that the geology of the play is well understood and documented, the expected value should be a reliable estimate of the potential of that play. Thus, expected values for the potential are the values most often adopted for economic analysis.

Estimate of resources in immature and conceptual plays

Within a mature basin the resources in immature and conceptual plays can be estimated using the principle of the nonparametric discovery process model. A play resource discovery sequence was generated by compiling the play resources (the sum of the expected potential and discovered resource) for each mature play and their discovery dates (the discovery date of the first pool in each play) (Fig. 9). If it is assumed that the mature plays belong to a single population the nonparametric discovery process model can be used to estimate both the number and individual sizes of the conceptual plays within the basin (Fig. 10).

The play discovery sequence of the Mannville Group (Fig. 9) was analyzed by the non-parametric discovery process model from which the expected potential (313 790 x 10^6 m^3) and probable potential (1 101 100 x 10^6 m^3) of the immature and conceptual plays (Fig. 10) can be estimated. The term "conceptual plays" means that new plays may be established by revising the present play definitions. Consequently, additional potential may be present.

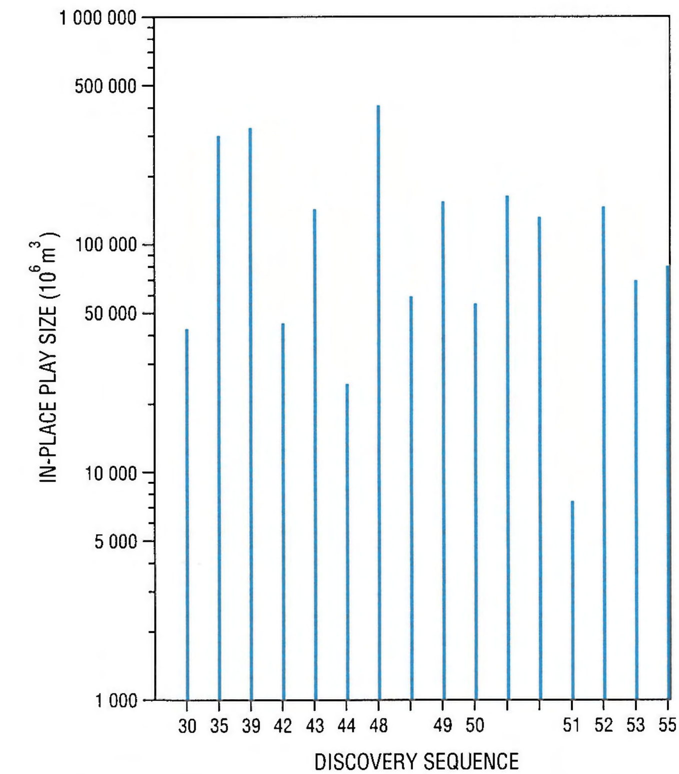


***Figure 9.** Play resource discovery sequence of the Mannville Group.*

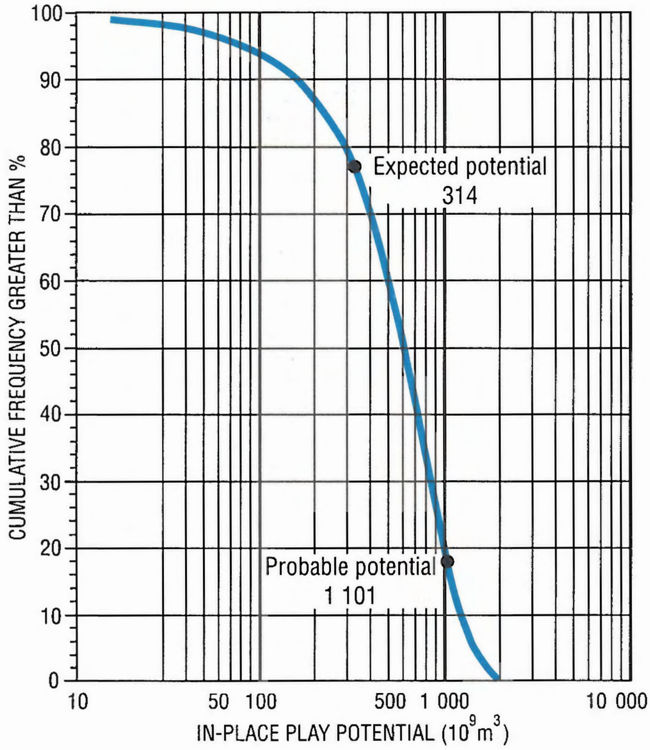


Figure 10. Play potential distribution conditioned on the sum of all play resources.

GEOLOGICAL FRAMEWORK

Depositional setting and tectonic elements

A number of reports on the Mannville Group have been published recently (Cant, 1989; Hayes et al., 1994) which have outlined many aspects of the geology of the unit. This discussion will review the regional geology of the Mannville Group in order to set the context of the play types defined in this report.

The Mannville Group is a clastic wedge of Barremian to Early Albian age deposited in a foreland basin associated with the development of the Cordillera by overthrusting. The unit reflects the beginning of a new phase of foreland subsidence and it lies on an unconformity cut during foreland uplift after the Jurassic subsidence phase. The lithostratigraphic nomenclature used in different areas (Fig. 11) generally reflects the local lithological successions (Fig. 12). Transitional zones exist between the various areas. These stratigraphic units, utilized in numerous databases, are the basis for the subdivision of the pools into "plays" in this assessment. Commonly included in the Mannville (also in this assessment) is the Detrital or Deville Formation, a somewhat older, residual deposit lying in depressions on the basal unconformity, most continuously in southern Saskatchewan, but irregularly throughout the remainder of the basin.

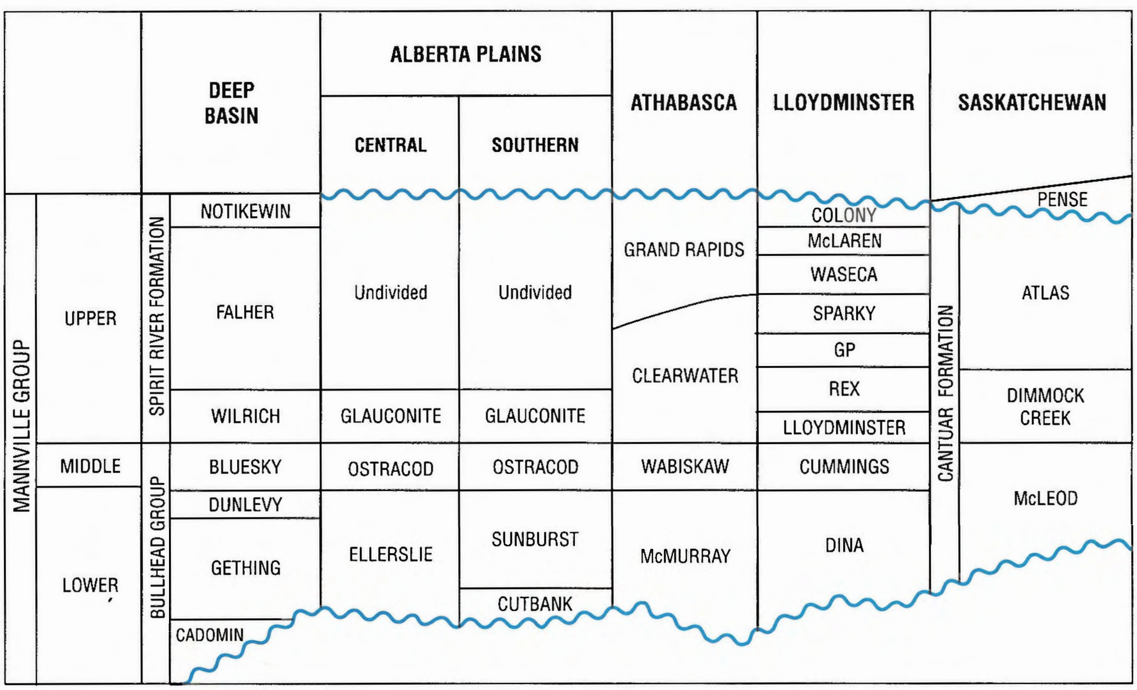


Figure 11. Lithostratigraphic units within the unconformity-bounded Mannville Group.

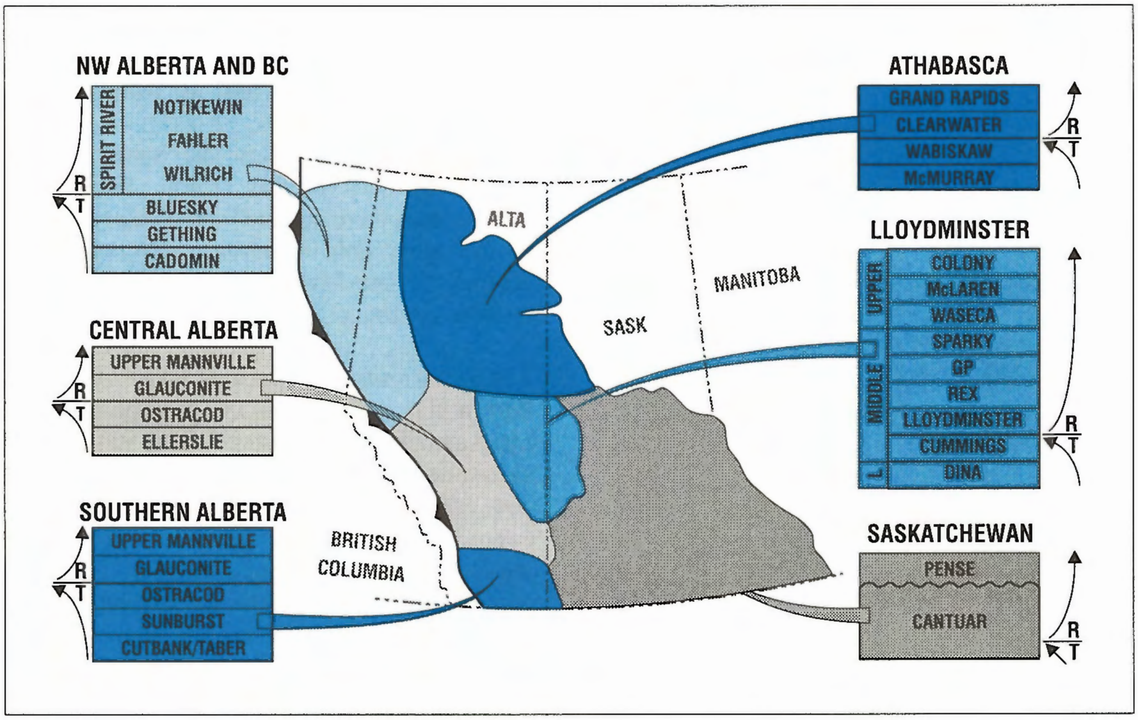


Figure 12. *Regional distribution of lithological units within the Mannville Group. T and R indicate the transgressive and regressive successions in each area.*

The highly variable lithostratigraphy of the Mannville Group results from several factors:

1) Areal variations in subsidence rates. Toward the orogen and northern parts of the basin, higher subsidence rates occurred because of the intensity and proximity of overthrust loading. The basal part of the Lower Mannville is believed to predate flexural subsidence, but this factor became increasingly important later in Mannville deposition. Local variations occur because of movement on basement structures, or solution of Devonian salt in eastern Alberta and Saskatchewan.

2) Variations in sediment supply rates. The most obvious factor influencing the rate of sediment supply to an area is the distance from the overthrust belt, the primary source of sediment for the basin. Generally, supply rates are higher in the west, but some anomalies occur because either ridges on the basal unconformity shield areas from sediment sources, or solution of Devonian salt created local depocentres into drainage was diverted.

3) The presence of major structural elements in the foreland (i.e., the Peace River Arch, Sweetgrass Arch, and Williston Basin). Peace River Arch contains a number of grabens, some of which were subsiding during Lower Mannville deposition, and the entire structure subsided faster than the remainder of the basin during Upper Mannville deposition. Sweetgrass Arch seems to have been relatively stable and highstanding during Mannville deposition, with the result that most of the unit onlaps against the arch. Williston Basin began to subside late in Upper Mannville deposition with the result that Upper Mannville shorelines parallel its margin, and the marine Pense Formation onlaps from the basin toward the northwest against the rest of the Upper Mannville.

4) Erosional topography on the basal unconformity. Topography on this surface is very complex. The orientation of ridges is roughly parallel to the orogen, suggesting that they were fundamentally controlled by foreland tectonics. The ridges and valleys on the unconformity in central Alberta result from tilting and erosion of the Palaeozoic to Jurassic rocks during the uplift period, between the deposition of the Jurassic Kootenay Group and the Mannville Group. Structures on the Peace River Arch influenced the location and orientation of local features, such as the Fox Creek Escarpment in north-central Alberta. The major ridges (Williams, 1963) influenced sediment supply markedly during Lower Mannville deposition such

that different facies occur on different sides. Even after the ridges were buried during Upper Mannville deposition, the topography influenced deposition, probably by differential compaction.

5) Longitudinal sediment supply. In common with many foreland basins, sediment was transported longitudinally along the basin, from south-southeast to north-northwest, during most of Mannville deposition. This pattern also reflects the subsidence gradient along the basin (Chamberlin et al., 1989) and probably resulted from differential loading along the orogen (Cant and Stockmal, 1989).

The irregular isopach pattern of the transgressive portion (Lower Mannville plus part of Middle Mannville) (Fig. 13) reflects a number of superimposed effects. In western Alberta and British Columbia, the thick Lower Mannville section appears to result from flexural loading. Minor subsidence of northeast-southwest trending grabens (part of the Peace River Arch) also occurred in the area, as shown by stratal thickening directly above the grabens. In Saskatchewan and northeastern Alberta, the accommodation space for Lower Mannville sedimentation probably resulted from salt solution of the Devonian Prairie Evaporite. The drainage patterns are generally northwest oriented, but in the west, valleys cut through the ridges. In many parts of the basin, the paleotopography on the basal unconformity is a prime control on stratigraphy, reservoir development, and petroleum trapping in the Lower Mannville.

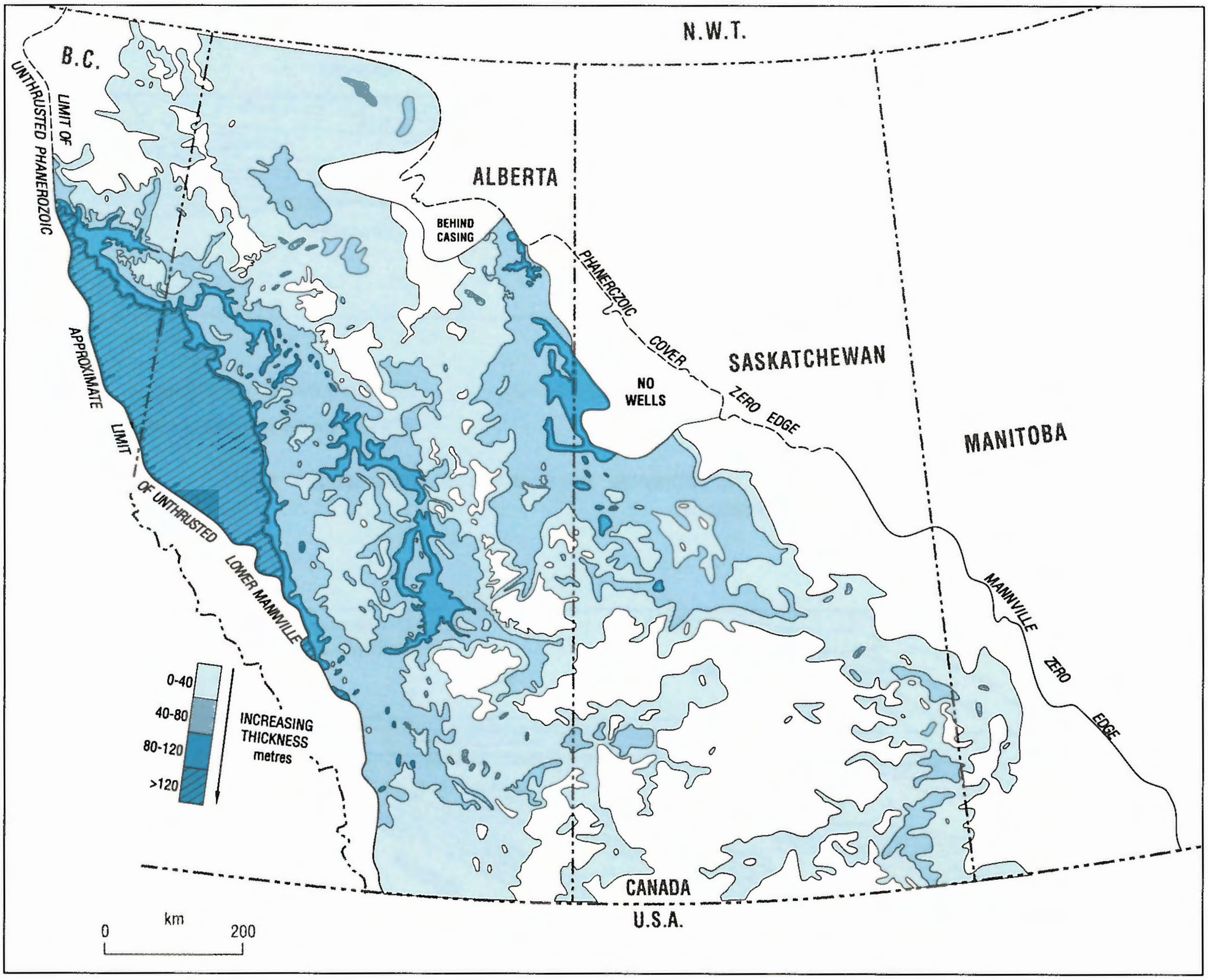


Figure 13. Isopach map of the transgressive portion of the Mannville Group, Western Canada Sedimentary Basin.

Mannville Group stratigraphy

The stratigraphy of the Mannville in eastern and western areas is shown in Figures 14 and 15. The dominant lithology in each unit is indicated on the diagrams. The Lower Mannville and the basal part of the Middle Mannville are transgressive, and a maximum flooding surface is present at the top of the Bluesky Formation in the west, and the Wabiskaw or Cummings formations in the east. The remainder of the Middle Mannville (Glauconite, Lloydminster formations), and the entire Upper Mannville are generally regressive, with the shoreline advancing progressively northward. The major difference in the stratigraphic scheme used here from the standard Energy Resources Conservation Board's correlation chart is the relations between the Bluesky and Glauconite formations in central Alberta. Regional correlations show that the Bluesky caps the Lower Mannville, is overlain by marine shale, and is transgressive. The Glauconite lies above marine shales, is overlain by nonmarine deposits, and shows a net regression (Fig. 16). Regional cross-sections show the two formations are completely distinct, but confusion may occur because of Glauconite lowstand sandstone bodies being present near the southern termination of the more continuous Bluesky Formation.

The Lower Mannville displays considerable variation in stratigraphy. Over much of the basin, the lowermost subunits (e.g., Cadomin, basal Gething Sandstone, Basal Quartz, Sunburst or Taber-Cutbank Sandstone, and perhaps the basal McMurray and part of the Dina formations) are believed to be unconformity-bounded (Figs. 17, 18). They are relatively pure sandstones and/or conglomerates, and

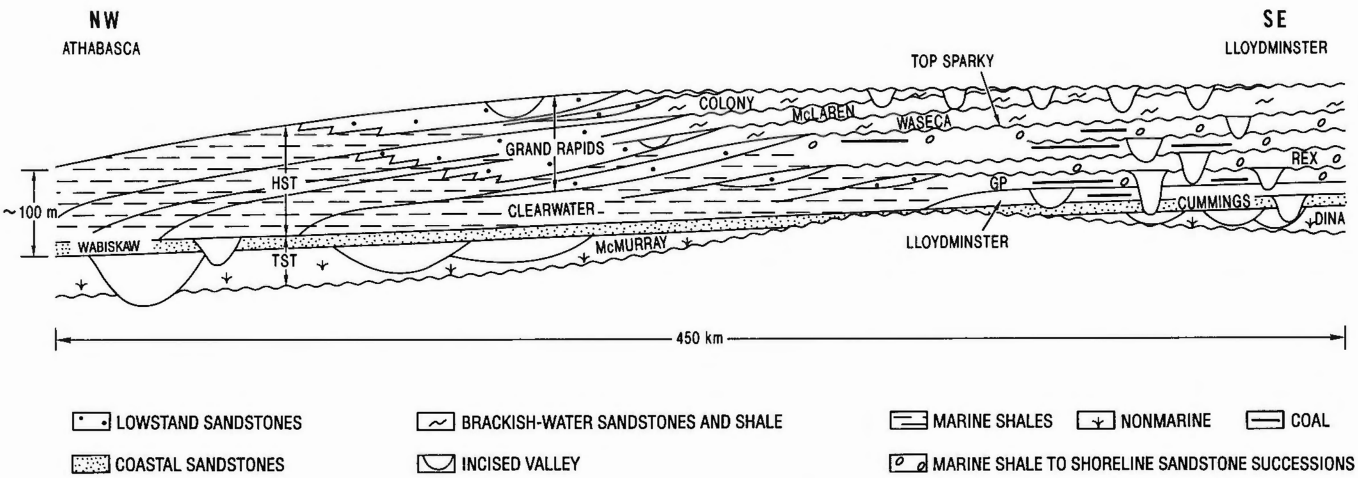


Figure 14. *Mannville stratigraphic relations on a cross-section from Lloydminster to Athabasca.*

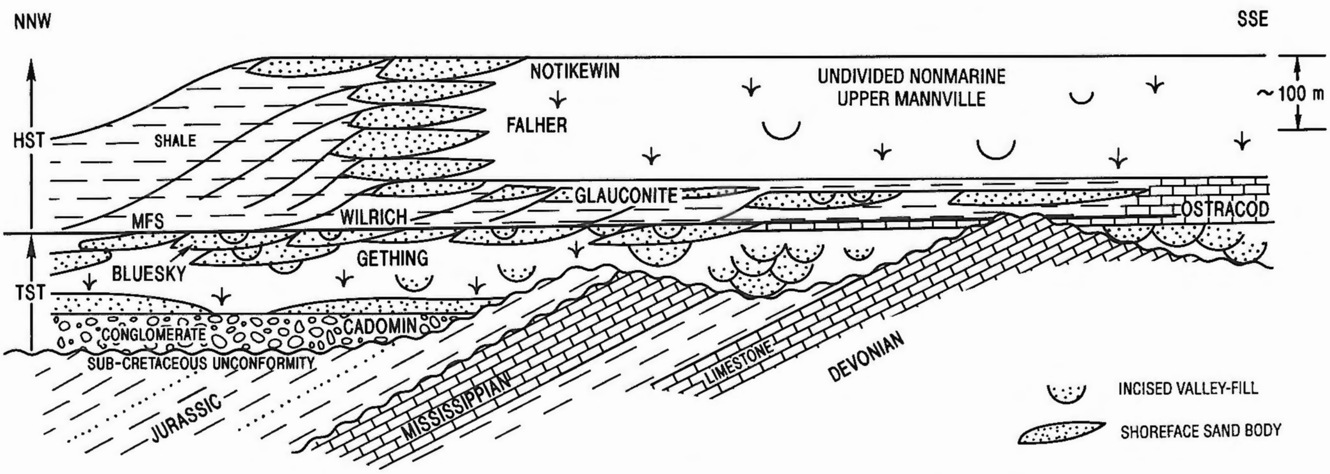


Figure 15. *Mannville stratigraphic relations on a cross-section from central Alberta to northeast British Columbia.*

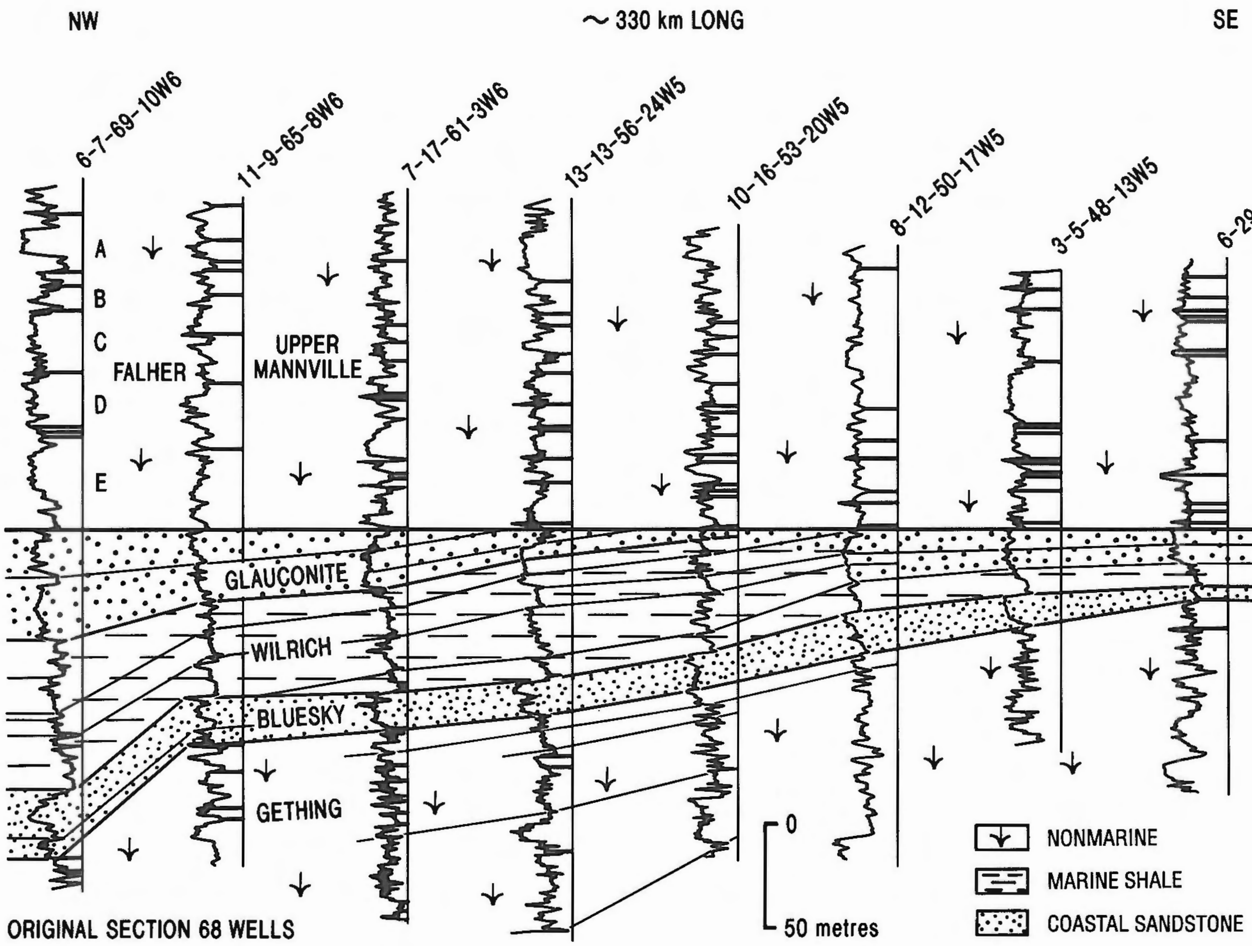


Figure 16. *Gamma-ray log cross-section from west-central Alberta, showing the stratigraphic relations between the Bluesky and Glauconite formations.*

infill topography on the basal unconformity. Some of these units have been dated by pollens and spores and have proven to be older than the remainder of the Lower Mannville. The Cadomin is Barremian in age, and the basal McMurray in northeastern Alberta has been dated as old as latest Valanginian or Hauterivian (Burden, 1984). Some of these basal units have been recognized as separate and older than the remainder of the Mannville (Carrigy, 1973). The basal deposits are not necessarily the same age in different parts of the basin.

These lowermost nonmarine deposits are believed to pre-date the initiation of flexural subsidence, as judged from the limited palynological data, their quartz- and chert-dominated sandstone and conglomerate lithologies, and their unconformable relationships with younger Mannville sediments. They are the result of trapping of sediment in erosional topographic depressions on the unconformity surface, as indicated by the map of the transgressive deposits (Fig. 13). In southern Alberta, the braided-river (or amalgamated channel) sandstones and conglomerates were deposited in valleys cut on the basal unconformity and were highly influenced by the shape and topography of the erosion surface. In the west, the Cadomin Conglomerate and Cutbank Sandstone onlap to the east, against erosional escarpments on the unconformity.

The petrology of the upper part of the Lower Mannville (increased proportions of lithic and volcanic grains) indicates it was deposited as a result of increasing orogenic activity. Accommodation space was generated by Cordilleran overthrust loading and the resulting flexural subsidence of the foreland. Because of some combination of eustatic rise, westward tilting of the craton, and flexural subsidence, relative sea-level rose, and the northern Boreal Sea began to transgress from the northwest. In western Alberta, the Lower Mannville (Gething Formation) is nonmarine and is dominated by shales and coals, due to high subsidence rates and abundant sediment supply. The thick sandstone bodies interrupting the fine grained, nonmarine Gething deposits are interpreted as valley-fills. In central Alberta, the topography on the unconformity restricted sediment supply and some valleys were partly filled by marine deposits, and thin beds of micritic limestone occur locally. In eastern areas (with lower sediment supply because of distance from the orogen), the marine transgression began earlier, as indicated by estuarine infill of channels in the McMurray Formation.

Lower Mannville deposition was terminated by acceleration of the Boreal transgression, during which Middle Mannville shoreface deposition (Bluesky, Wabiskaw, Cummings formations) occurred over much of the basin. The stratigraphy of the Middle Mannville is complex because of numerous fluctuations in relative sea level. Behind the southernmost shorelines is a unit of lagoonal to open-marine carbonates and shales known as the Ostracod Limestone, the Calcareous Member, or the Bantry Shale (Figs. 12, 15).

Increased sediment supply to the basin (occasionally greater than subsidence rates) caused the Upper Mannville regression, which drove the shoreline back to the north-central portions of the basin (Fig. 15). In the west, the most widespread regression is encompassed within the Glauconite Formation, which consists of a shoreface sandstones with equivalent offshore shales (the Wilrich Member). Numerous incised valleys attest to the fluctuations in relative sea level during deposition of the Glauconite Formation. In the eastern part of the basin, thin, low-energy shoreface successions (Lloydminster, GP, Rex, Sparky formations) aggraded at the same time (Fig. 14). Each of these thin shoreface to deltaic successions is also cut by numerous, large, valley systems which discharged sand northwestward. This resulted in lowstand shoreface sandstone bodies being deposited and encased within the shale-rich Clearwater Formation. The major regression in the east occurs at the top of the Sparky Formation, where it is abrupt, reflecting a fall in relative sea level and a major seaward

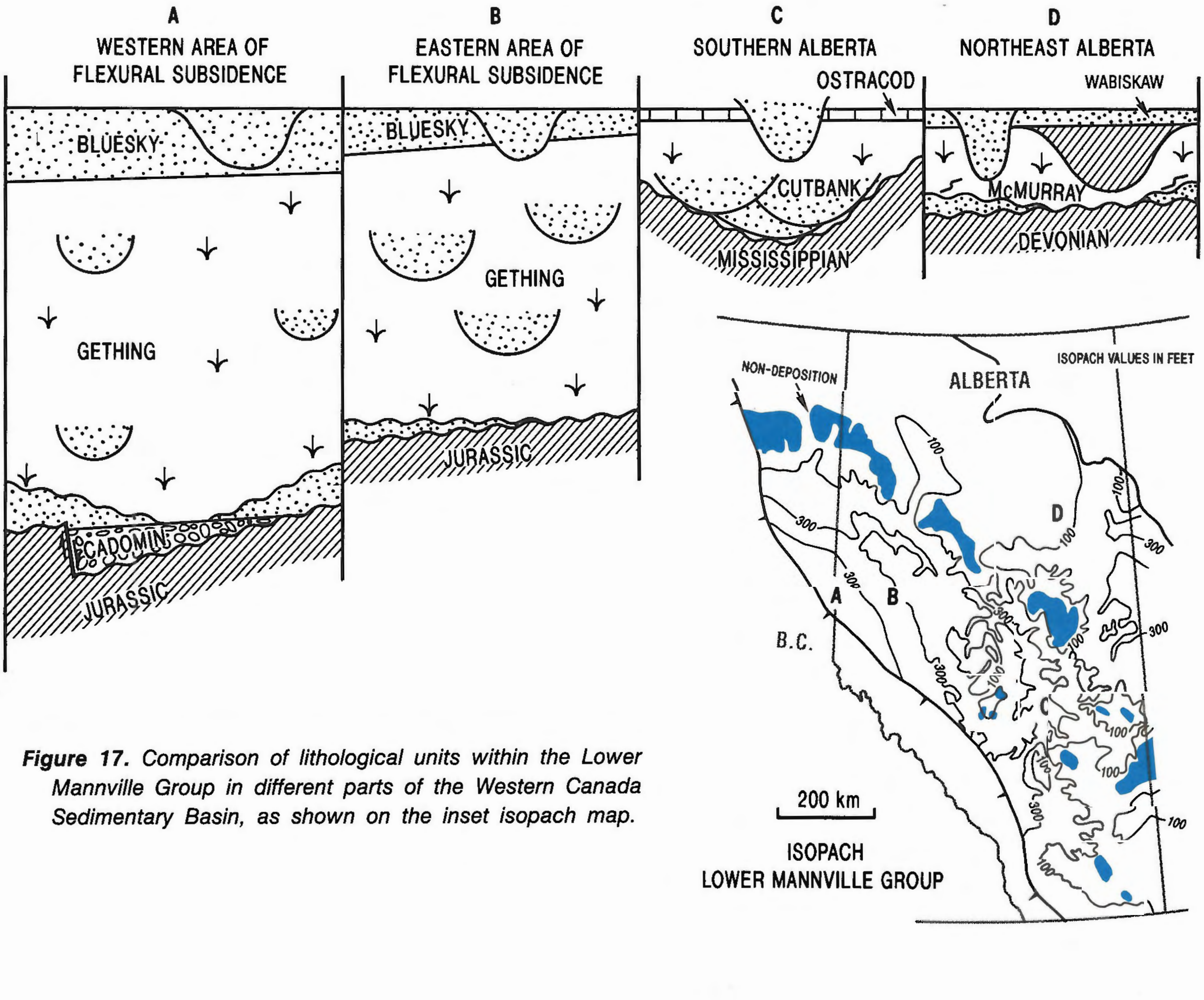


Figure 17. Comparison of lithological units within the Lower Mannville Group in different parts of the Western Canada Sedimentary Basin, as shown on the inset isopach map.

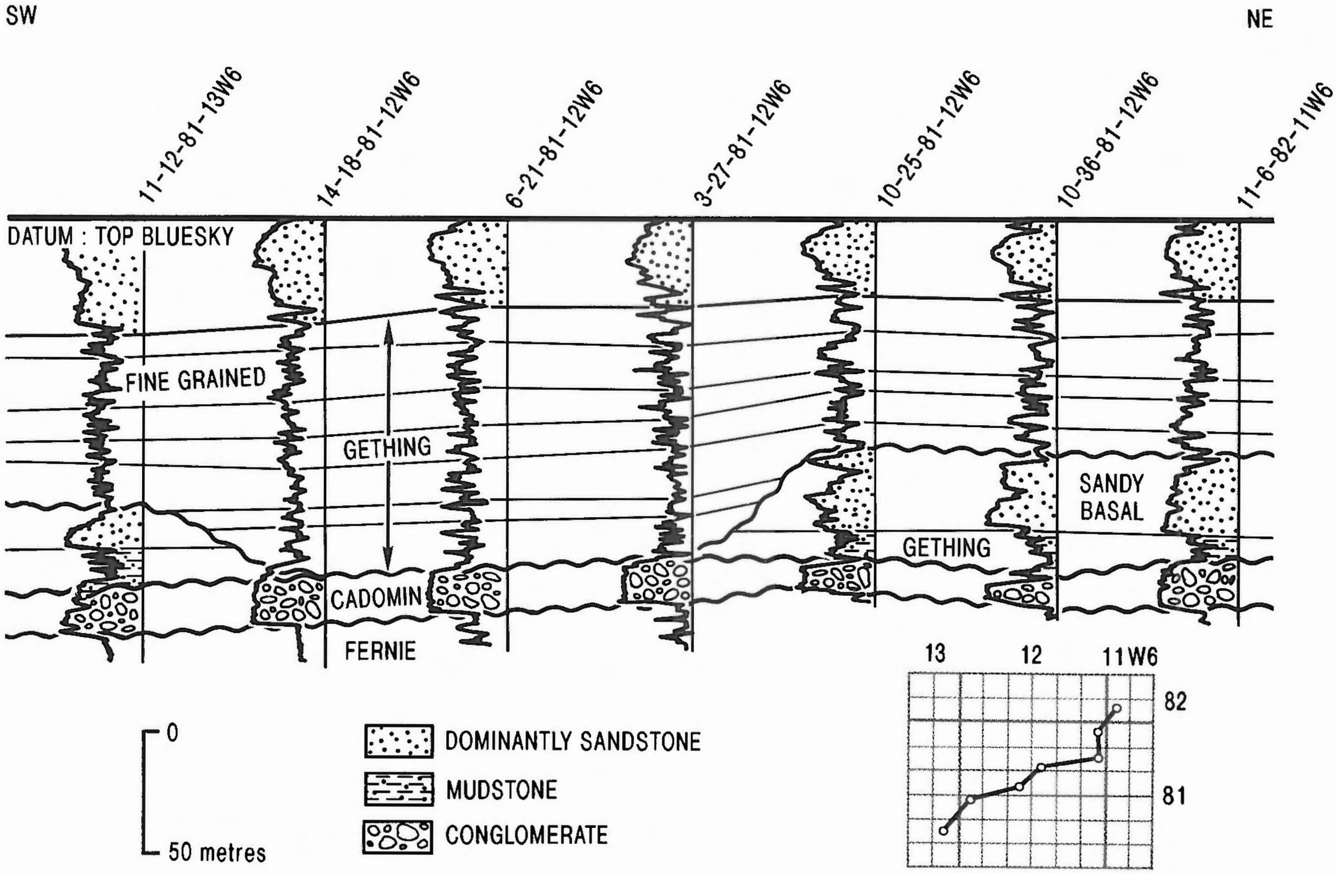


***Figure 18.** Gamma-ray log cross-section from northwest Alberta showing stratigraphic relations in the Cadomin–Gething interval.*

facies shift. Sandstone of the basal Grand Rapids Formation onlaps onto the post-Sparky unconformity surface. The top of the Sparky Formation is approximately equivalent to the top of the distal end of the Glauconite Formation (including nonmarine deposits behind seaward shoreface sandstones).

Above this surface of abrupt regression, the undivided Upper Mannville consists of fine-grained, nonmarine deposits in the south. The few thick sandstones are interpreted as valley-fills cutting into the finer grained facies. To the north, the shoreface sandstones and conglomerates of the Falher and Notikewin members are stacked at the southern margin of the Peace River Arch, with offshore marine, coarsening-upward shale to sandstone successions grading off to the north. Each of these shoreface successions includes a disconformity, indicating a drop in relative sea level, with relatively small volumes of lowstand shoreface sandstones to the north.

Eastward, the stratigraphic situation is more complex. Relative sea-level fluctuations produced alternating deposition of highstand, restricted-marine, low-energy littoral deposits of the Colony, McLaren, and Waseca formations, and stacked and amalgamated lowstand shoreface sands of the Grand Rapids Formation. Because of the low subsidence rates and the influence of solution of Devonian salt on basin shape, the highstand and lowstand deposits are localized in different areas (the Lloydminster and Athabasca areas, respectively).

In the Upper Mannville, regional correlations have shown that disconformities merge eastward into the areas of slower subsidence. Several of the Falher successions exhibit this feature when traced into eastern Alberta. Because of the merging, the unconformities are commonly detectable by paleontological means. In Saskatchewan, Lower Mannville sediments fill valleys cut into uplands composed of Jurassic clastic rocks and Mississippian and Devonian carbonates. However, the most extensive valley systems are believed to be in the basal Upper Mannville (Glauconite equivalents). Upper Mannville sediments onlap against the higher areas on the unconformity. In the large area overlying the Prairie Evaporite in south-central Saskatchewan, the Mannville equivalent is termed the Cantaur Formation, but correlations with stratigraphic units in the Lloydminster area remain tentative.

Play definitions

To comply with the time requirements for completion of the assessment, the Mannville's 13 000 gas pools were classified using the pre-existing provincial regulatory board stratigraphic and production databases. The subdivision of Mannville pools was accomplished by dividing the pools, based on their assigned production intervals, into groups defined stratigraphically and areally, as shown in Figure 2. This procedure does not necessarily group pools in "plays" that are as uniform as those resulting from the detailed geological analysis which was completed in other assessment studies by the GSC in the basin (e.g., Reinson et al., 1993). However, it seems to be a reasonable approximation to this type of analysis because each of the Mannville "plays" has been defined to contain gas pools with relatively uniform histories of hydrocarbon generation, mirgration, and entrapment (Fig. 2).

ESTABLISHED PLAYS

Northwest Alberta/northeast British Columbia

Spirit River play

Play definition

This play includes all gas pools and prospects in sandstones and conglomerates of the Falher and Notikewin members of the Spirit River Formation and includes many conventional pools, but also many classed as "Deep Basin" accumulations by Masters (1984) (Fig. 19). For the latter, the trapping mechanism has been addressed by many authors (Masters, 1979, 1984; Cant, 1983; Gies, 1984; Varley, 1984). The mechanisms invoked involve the following factors: 1) generation of gas in the deeper part of the basin, 2) preservation of reservoir zones with high porosity and permeability, 3) low rates of gas leakage updip from the reservoirs because of low permeability of the surrounding rocks, and 4) low relative permeability to gas because of downdip water flow. In the case of the Falher reservoirs, it appears that gas is still being generated (Welte et al., 1984).

Geology

The predominant reservoirs are the Falher shoreface conglomerates (with subordinate coarse grained sandstone), as exemplified by those of the Elmworth field. These shoreface deposits comprise parts of transgressive-regressive cycles stacked at the southern margin of the Peace River Arch. Fine grained sandstones essentially surround the reservoirs and are tight because of quartz-overgrowth cementation, with permeabilities less than a millidarcy. The chert-pebble conglomerates have not suffered much diagenesis and permeability is up to four darcies. To the west in British Columbia, shoreface conglomerates have poorer reservoir properties because of kaolinite cementation. To the east, the rocks are generally wet (Rahmani, 1984). In the top ten discovered pools in this group, Falher reservoirs account for eight. The others occur in shoreface conglomerates of the Notikewin Member at Kaybob. The regional map of Jackson (1984) shows that these conglomerates are at the Notikewin transgressive limit, similar to the Falher conglomerates.

At Elmworth, and elsewhere in the Deep Basin, the volumetrically dominant "tight sands" are gas saturated, but have not proved to be economic long-term producers. The conventional conglomeratic reservoirs have been well delineated by drilling of the shorelines, and they are mapped as linear barrier ridges (Smith, 1984), each lying on a minor disconformity above a shoreface sandstone and are present mainly within the Falher A, B, and D successions. Each disconformity was generated by a fall in relative sea level in the Elmworth area, with isolated falling and lowstand shoreface deposits on the shelf (Fig. 20). Some of these deposits are known to contain conglomerates and may be future targets for exploration.

Exploration history

There have been 275 gas pools discovered in the Spirit River Formation of northwest Alberta and northeast British Columbia with a total in-place gas volume of 102 582 x 10^6 m^3. The largest gas pool to be discovered in this play is the Elmworth Falher A-1 pool, which has 10 284 x 10^6 m^3 gas-in-place (Figs. 19, 21; Table 1). The discovery of the Elmworth pool in 1970 (Masters, 1979) resulted not only in a great expansion of the scope of discoveries in this play, but also in the "Deep Basin" concept of hydrocarbon entrapment.

Play potential

The expected potential for this play is 28 888 x 10^6 m^3 gas-in-place. Based on this estimate, 22 per cent of the total play resources remains to be discovered. This estimate assumes a total pool population of 400 pools and predicts the largest undiscovered pool to have 1824 x 10^6 m^3 gas-in-place (Table 1; Fig. 22).

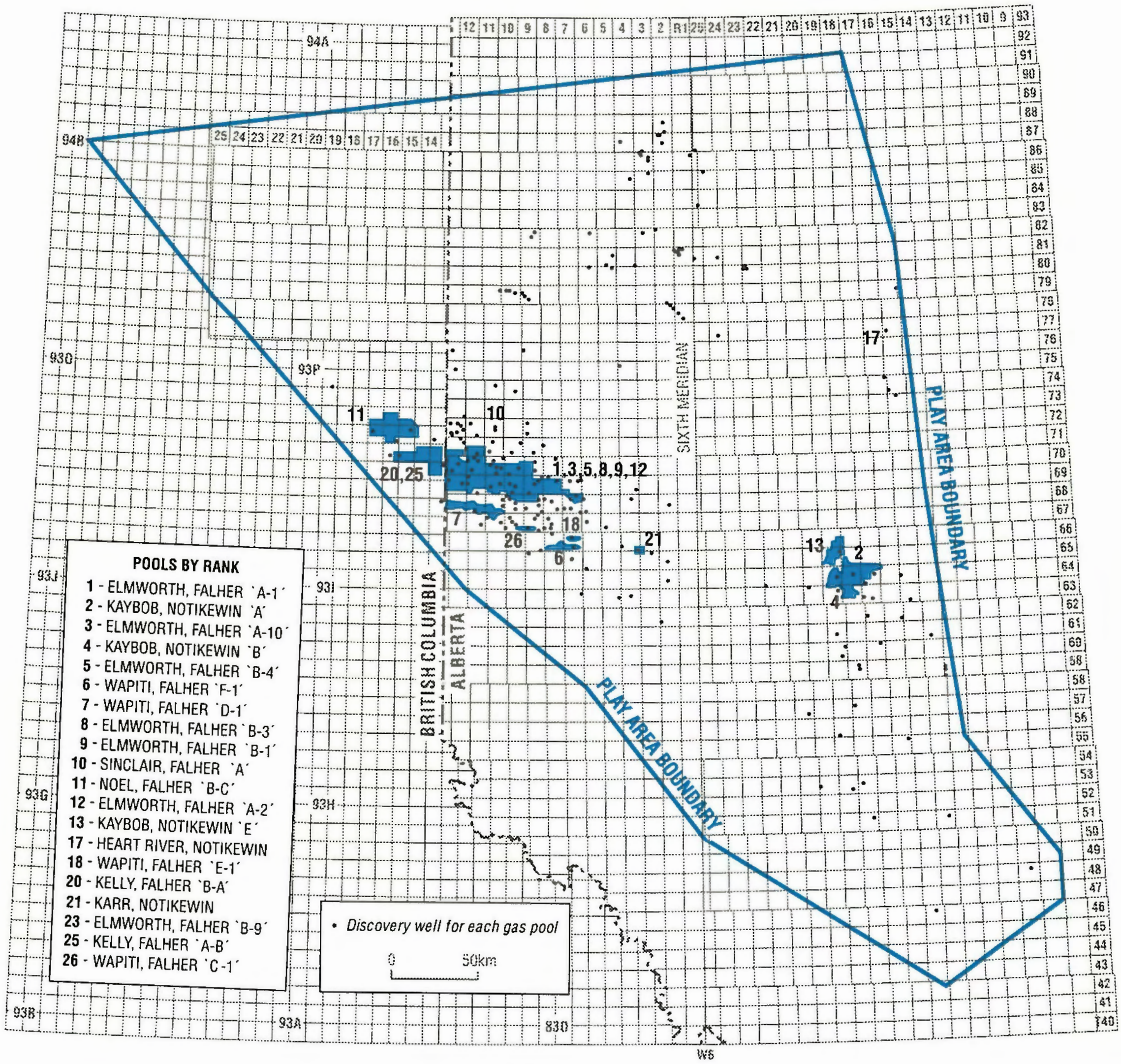


Figure 19. *Play map: northwest Alberta/northeast British Columbia–Spirit River play. Pools listed in Table 1.*

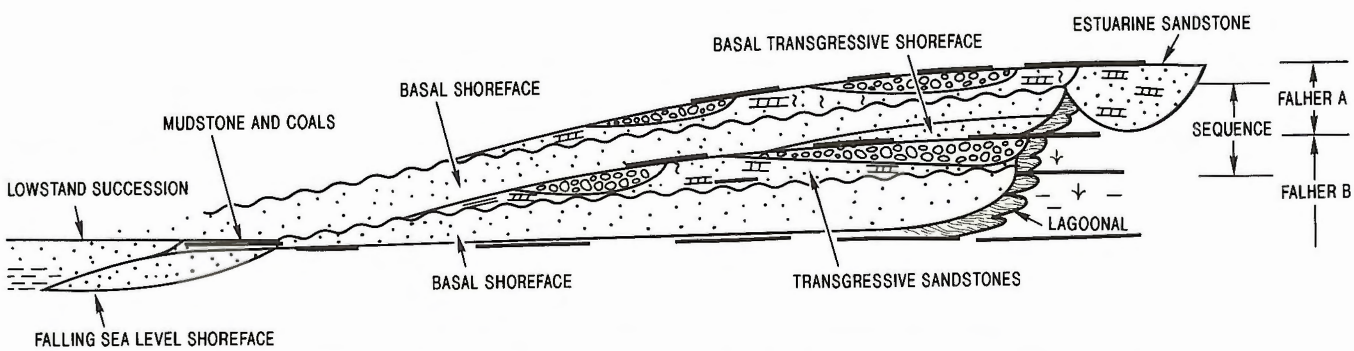


Figure 20. *Diagrammatic cross-section of Falher A and B cycles, showing unconformities, offshore sandstones, and transgressive, reservoir-quality conglomerates.*

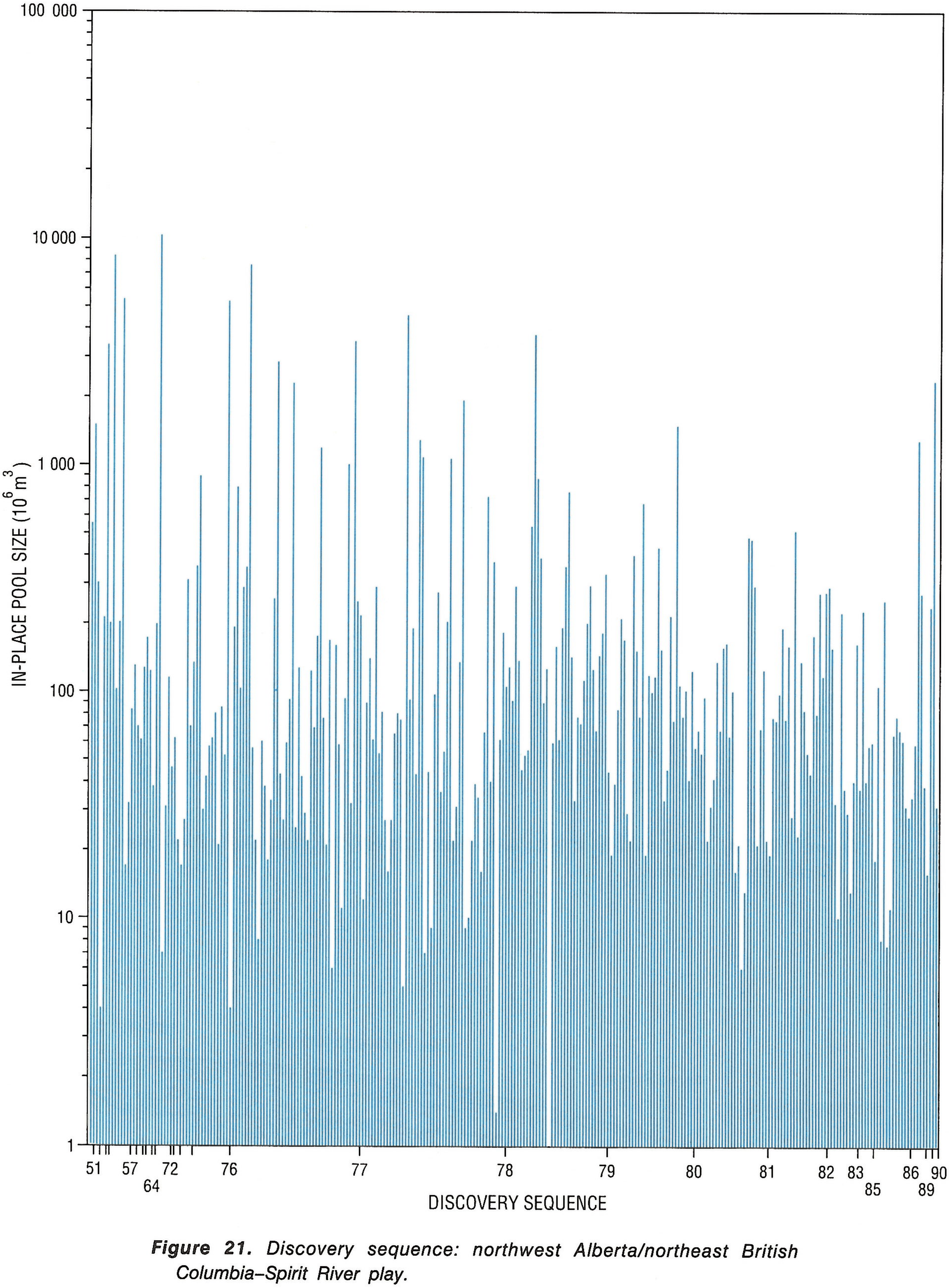


Figure 21. *Discovery sequence: northwest Alberta/northeast British Columbia–Spirit River play.*

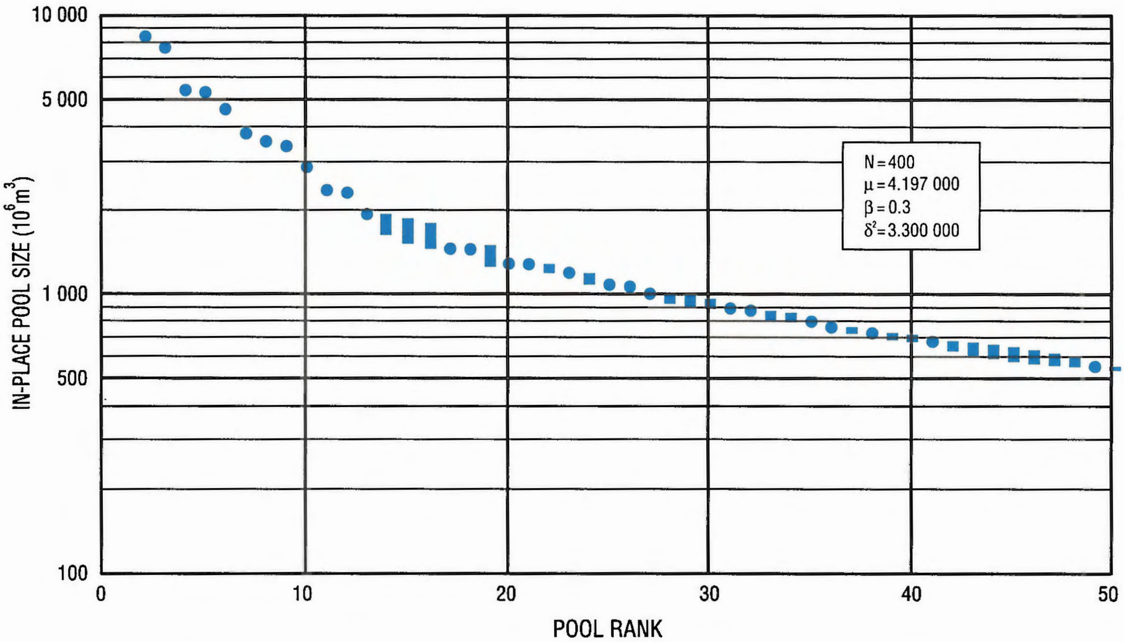


Figure 22. *Pool rank plot: northwest Alberta/northeast British Columbia–Spirit River play.*

Table 1

Summary of the northwest Alberta/northeast British Columbia–Spirit River play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Elmworth, Falher A-1	NA	10 284	1970
2	Kaybob, Notikewin A	NA	8 347	1957
3	Elmworth, Falher A-10	NA	7 613	1977
4	Kaybob, Notikewin B	NA	5 380	1957
5	Elmworth, Falher B-4	NA	5 273	1976
6	Wapiti, Falher F-1	NA	4 582	1978
7	Wapiti, Falher D-1	NA	3 765	1979
8	Elmworth, Falher B-3	NA	3 515	1977
9	Elmworth, Falher B-1	NA	3 378	1955
10	Sinclair, Falher A	NA	2 852	1977
11	Noel, Falher B-C	NA	2 351	1989
12	Elmworth, Falher A-2	NA	2 298	1977
13	Kaybob, Notikewin E	NA	1 932	1978
17	Heart River, Notikewin	NA	1 500	1951
18	Wapiti, Falher E-1	NA	1 490	1980
20	Kelly, Falher B-A	NA	1 287	1978
21	Karr, Notikewin	NA	1 283	1988
23	Elmworth, Falher B-9	NA	1 190	1977
25	Kelly, Falher A-B	NA	1 082	1978
26	Wapiti, Falher C-1	NA	1 067	1978
Initial in-place volume (discovered) (10^6 m^3)			102 582	
Initial in-place volume (potential) (10^6 m^3)			28 888	
Per cent of play resources undiscovered			22	
Total pools discovered			275	
Total pool population			400	

NA, nonassociated gas

Bluesky play

Play definition

This play includes all gas pools and prospects contained within the Bluesky Formation in the northwest Alberta and northeast British Columbia play area (Fig. 23). Both conventional and "Deep Basin" gas pools are included in this play.

Geology

The Bluesky Formation was deposited as a series of regressive pulses during the overall southward transgression of the Boreal Sea. It can be divided into three main facies: 1) regressive, coarsening-upward, offshore to shallow-marine deposits, 2) transgressive conglomerate lags, and 3) incised valley-fill deposits. These divisions also characterize the types of hydrocarbon traps found within the Bluesky Formation in northwest Alberta and northeast British Columbia. The contact between the Bluesky and the underlying coastal plain deposits of the Gething Formation is gradational and is generally picked at the first occurence of marine sandstones. Marine shales of the Wilrich Member overlie the Bluesky Formation.

The Boyer Bluesky A pool (Figs. 24, 25) is the largest gas pool discovered in the Bluesky play and is located on the northeast side of the pre-Cretaceous Keg River High. The Bluesky Formation in this area consists of a series of coarsening-upward, regressive, offshore to shallow-marine sandstones that onlap to the southwest, onto the Keg River High (Figs. 24, 25; (Warters, 1994). Gas is trapped within shallow-marine sandstones encased by marine shales of the Bluesky Formation and the overlying Wilrich Member of the Spirit River Formation. The Pine Creek Bluesky A pool is the eighth largest discovered gas pool in the Bluesky play and it is an example of a hydrocarbon trap in an incised valley-fill. Gas is produced from estuarine channel sandstones of the Bluesky Formation (Figs. 26, 27; (Hardy, 1989). The Ring/Pedigree Bluesky A pool, which is a multi-pool field consisting of the Ring-Border and Pedigree pools (as defined by the GSC), is an example of a hydrocarbon trap in a transgressive lag (Sturrock and Dawson, 1991). In the Ring/Pedigree field, production is from the Montney, Bluesky, and Gething formations. The British Columbia Ministry of Energy, Mines, and Petroleum Resources divides the total gas-in-place amongst the units as follows: Montney 85 per cent, Bluesky 5 per cent, and Gething 10 per cent. For assessment purposes the GSC has subdivided the Ring/Pedigree field into three pools, the Ring/Pedigree Bluesky A, Ring/Pedigree Gething A, and the Ring/Pedigree Montney A.

Exploration history

There have been 304 gas pools discovered in the northwest Alberta and northeast British Columbia/ Bluesky play, with a total discovered in-place, gas volume of 105 478 x 10^6 m^3. The largest gas pool discovered is the Boyer Bluesky A pool with 16 232 x 10^6 m^3 of gas-in-place. It was discovered in 1974. Three of the top four Bluesky gas pools are located to the northeast of the pre-Cretaceous Keg River High (Figs. 23, 28; Table 2).

Play potential

The expected potential for the northwest Alberta/ northeast British Columbia–Bluesky play is 48 585 x 10^6 m^3 gas-in-place, based on a total pool population of 500 pools. This estimate indicates that 32 per cent of the total gas resources for this play remains to be discovered. The largest undiscovered gas pool is predicted to have 4694 x 10^6 m^3 of gas-in-place (Table 2; Fig. 29).

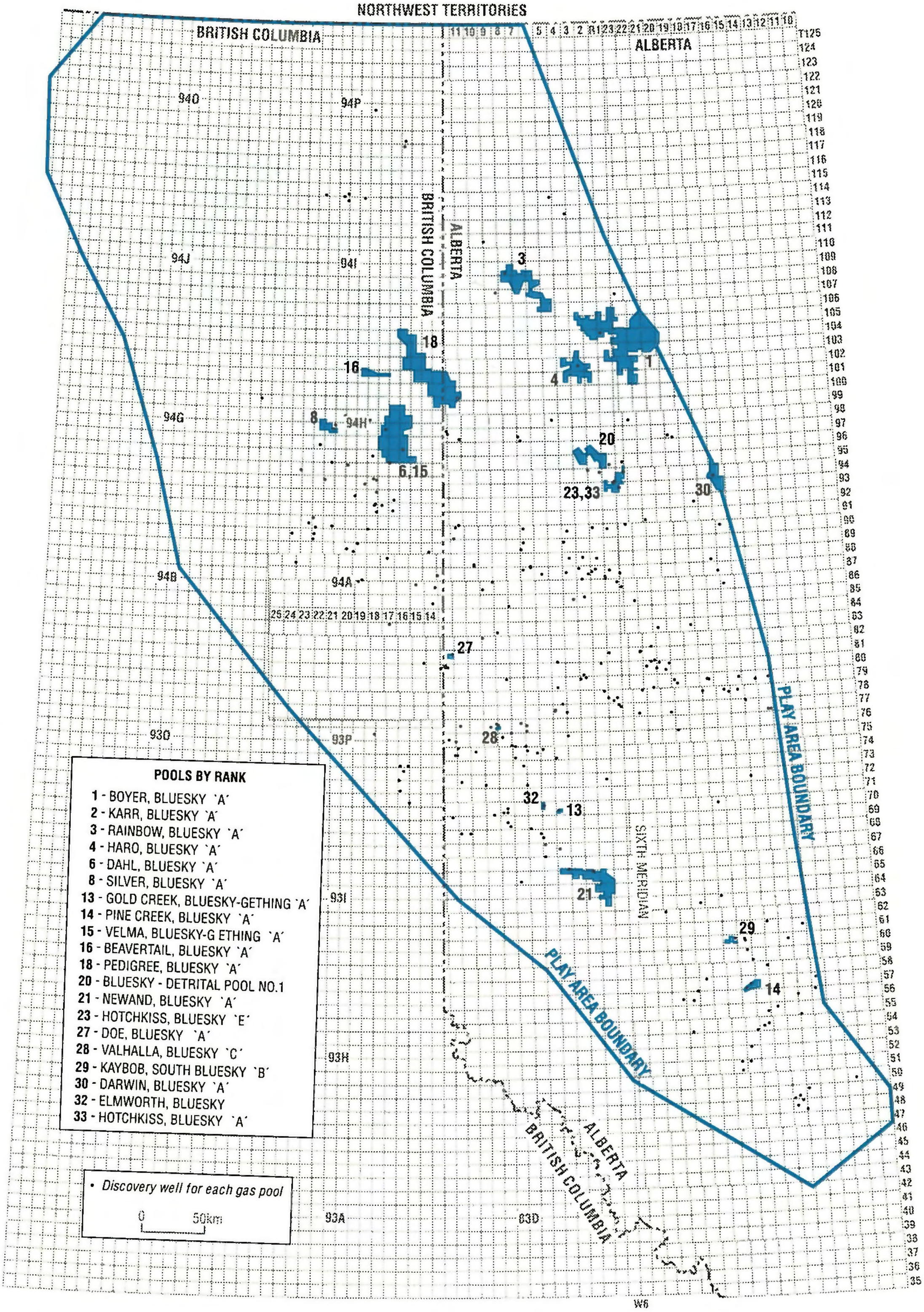


Figure 23. *Play map: northwest Alberta/northeast British Columbia–Bluesky play. Pools listed in Table 2.*

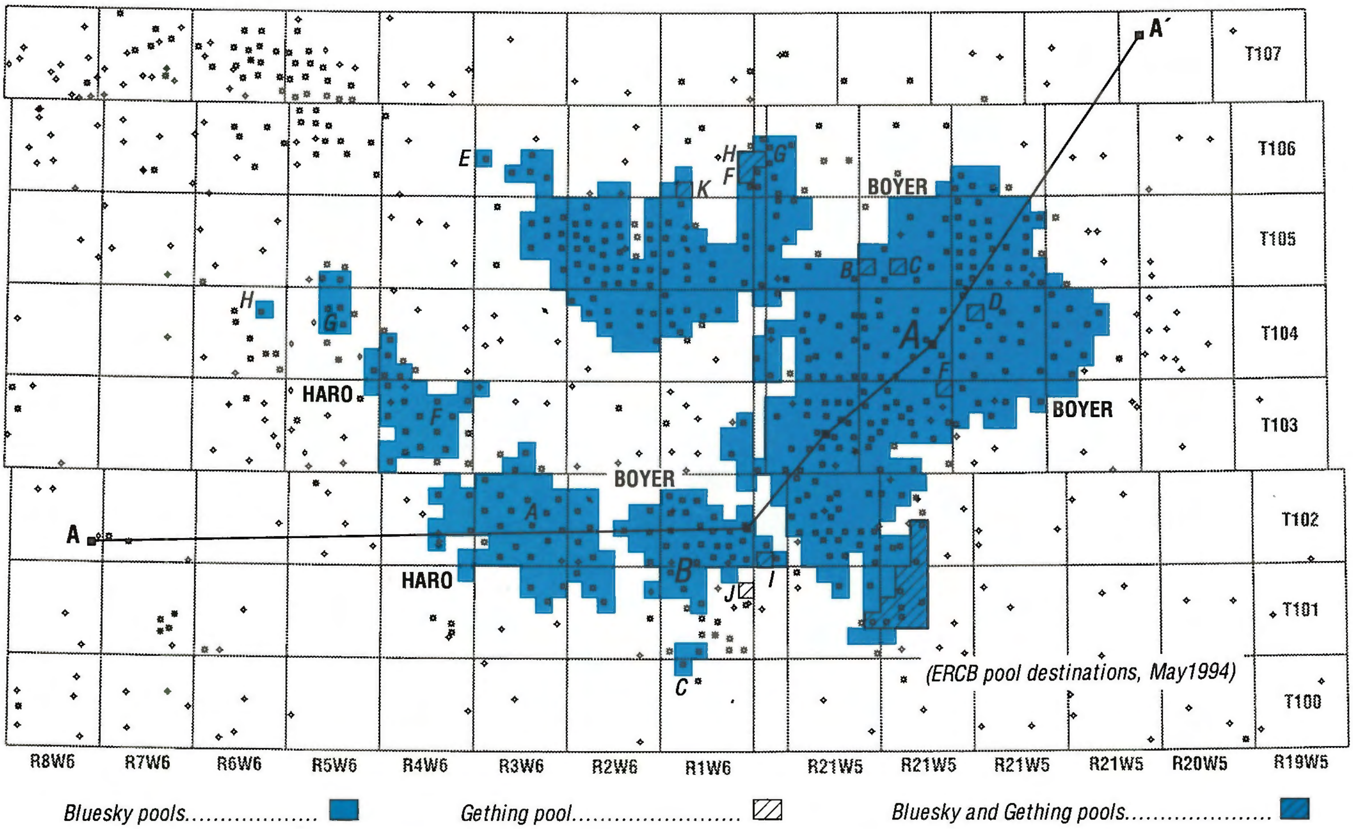


Figure 24. *Map of the Boyer Bluesky A and B gas pools (Warters, 1994). Location of cross-section illustrated in Figure 25.*

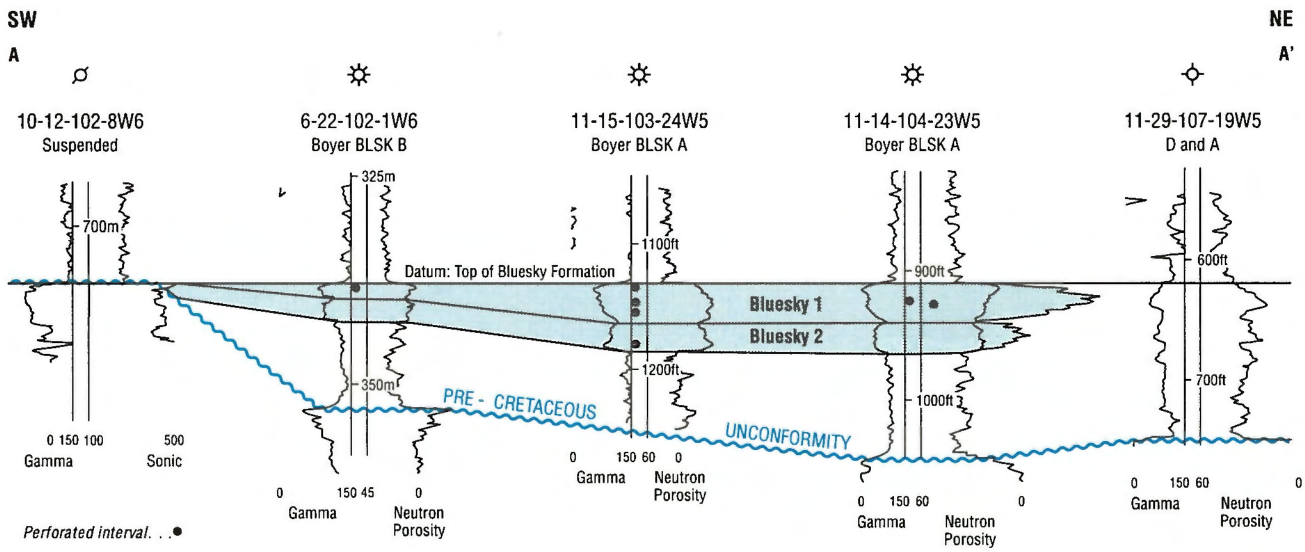


Figure 25. *Stratigraphic cross-section through the Boyer Bluesky A and B gas pools. Section illustrates the two transgressive shoreface sandstones of the Bluesky Formation which form the reservoirs in the Boyer Bluesky A and B gas pools (Warters, 1994).*

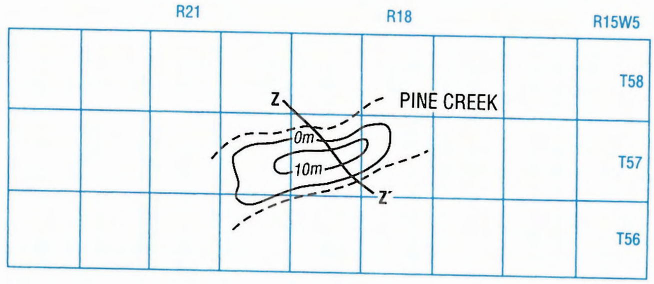


***Figure 26.** Distribution and thickness of the estuarine channel sandstones of the Blueksy Formation, Pine Creek Field. Contour interval 10 m (modified from Hardy, 1989).*

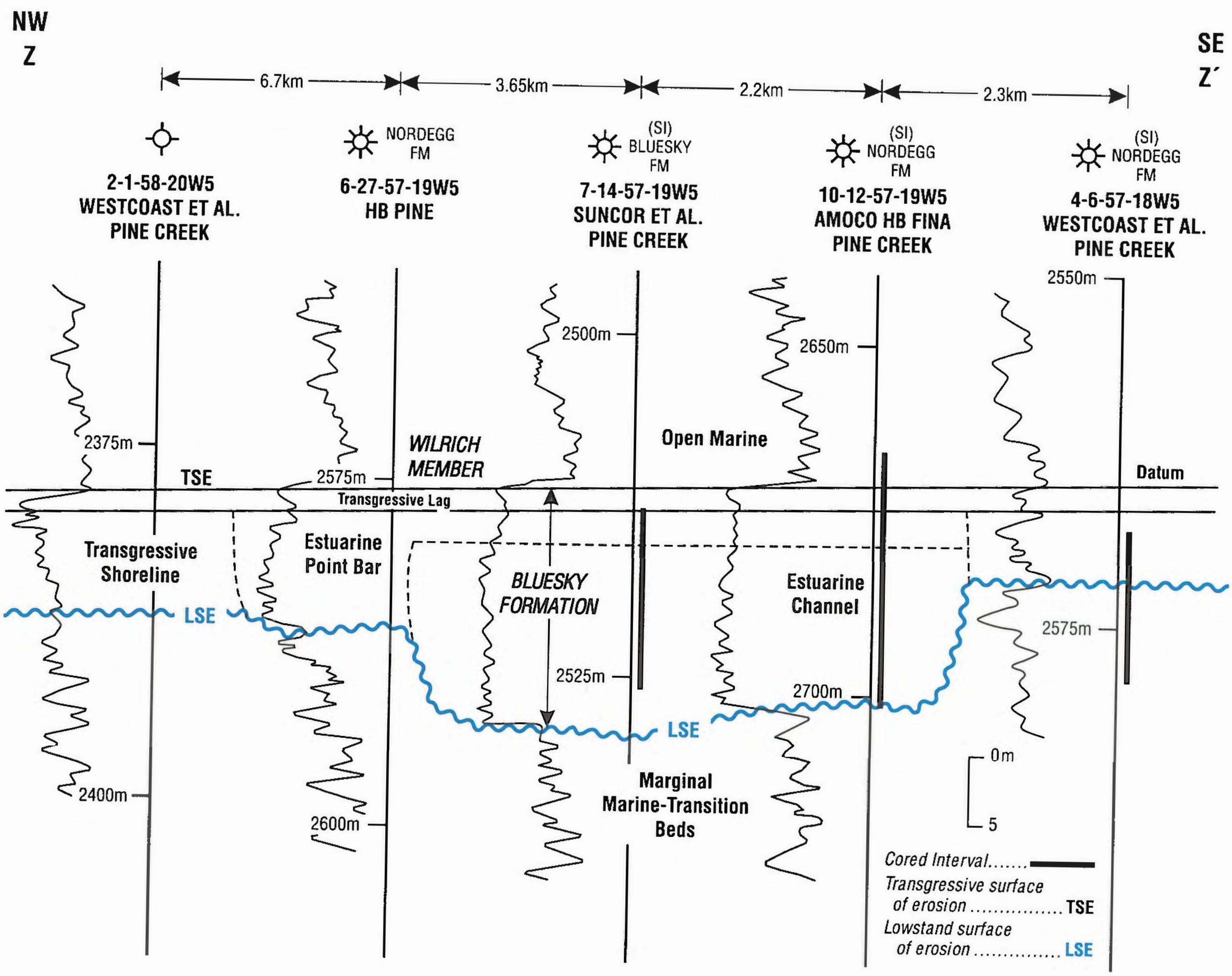


***Figure 27.** Stratigraphic cross-section across the Pine Creek Bluesky A gas pool. The valley-fill deposits at Pine Creek are estuarine channel point-bars and form the reservoir in the Pine Creek Bluesky A gas pool (modified from Hardy, 1989).*

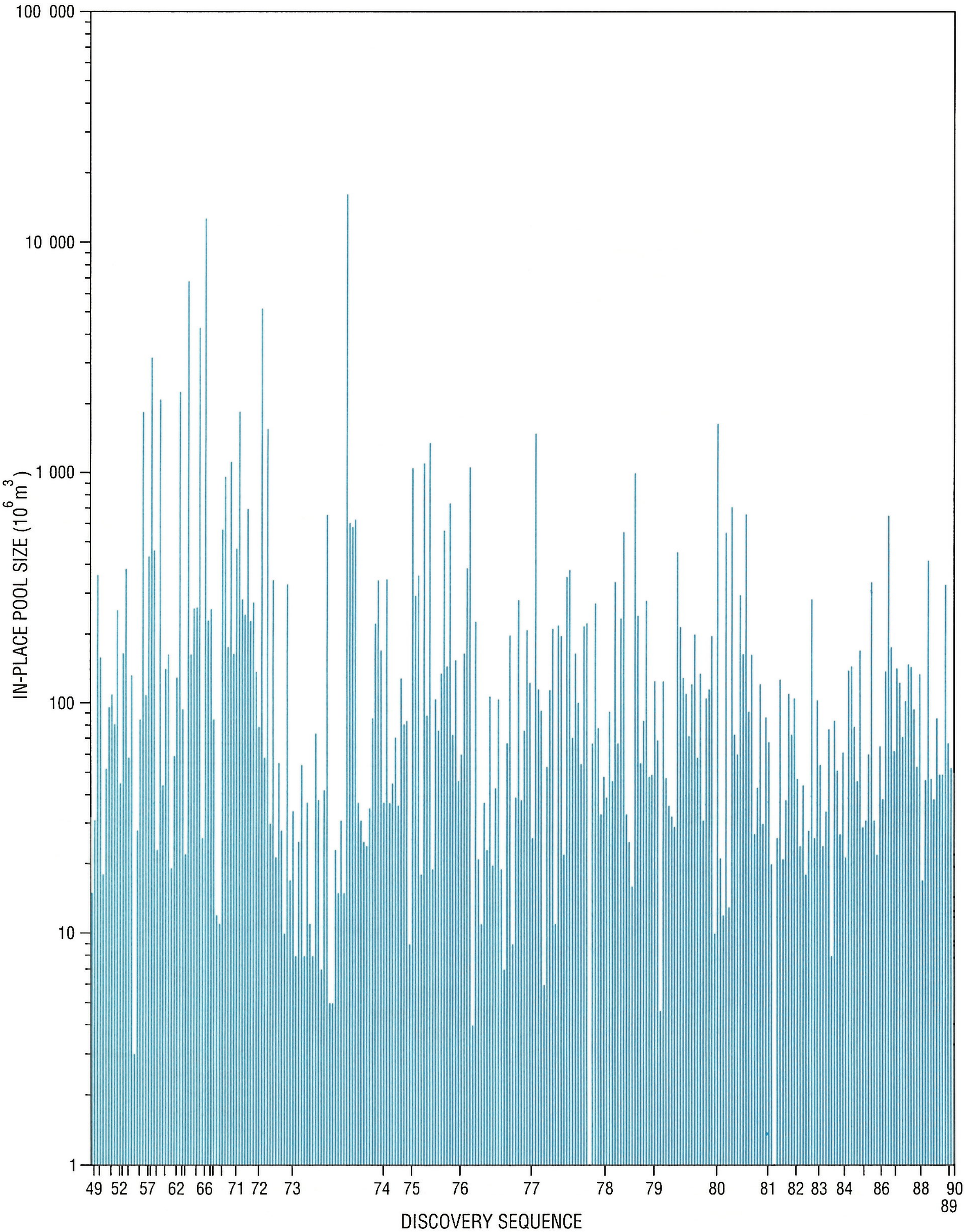


Figure 28. *Discovery sequence: northwest Alberta/northeast British Columbia–Bluesky play.*

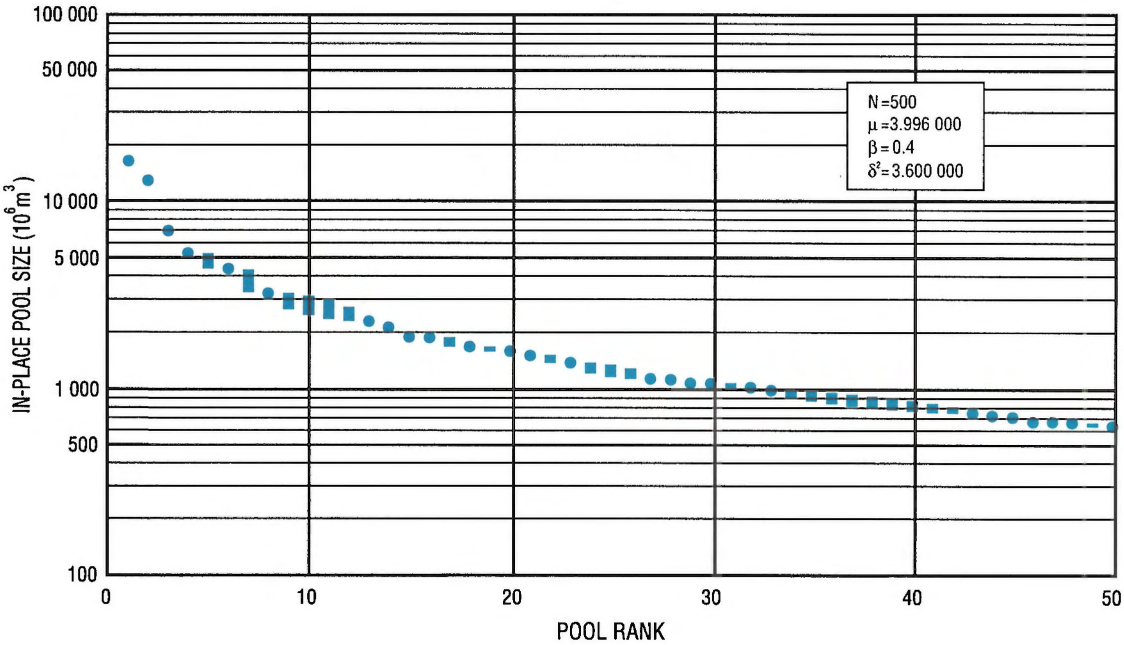


Figure 29. *Pool rank plot: northwest Alberta/northeast British Columbia–Bluesky play.*

Table 2

Summary of the northwest Alberta/northeast British Columbia–Bluesky play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Boyer, Bluesky A	NA	16 232	1974
2	Karr, Bluesky A	NA	12 737	1968
3	Rainbow, Bluesky A	NA	6 817	1965
4	Haro, Bluesky A	NA	5 197	1973
6	Dahl, Bluesky A	NA	4 288	1966
8	Silver, Bluesky A	NA	3 177	1960
13	Gold Creek, Bluesky–Gething A	NA	2 256	1963
14	Pine Creek, Bluesky A	NA	2 089	1961
15	Velma, Bluesky–Gething A	NA	1 852	1972
16	Beavertail, Bluesky A	NA	1 846	1957
18	Pedigree, Bluesky A	NA	1 647	1981
20	Bluesky–Detrital Pool No. 1	NA	1 557	1973
21	Newand, Bluesky A	NA	1 491	1978
23	Hotchkiss, Bluesky E	NA	1 355	1976
27	Doe, Bluesky A	NA	1 120	1971
28	Valhalla, Bluesky C	NA	1 108	1976
29	Kaybob South, Bluesky B	NA	1 064	1977
30	Darwin, Bluesky A	NA	1 057	1976
32	Elmworth, Bluesky	NA	1 005	1979
33	Hotchkiss, Bluesky A	NA	965	1971
Initial in-place volume (discovered) (10^6 m^3)			105 478	
Initial in-place volume (potential) (10^6 m^3)			48 585	
Per cent of play resources undiscovered			32	
Total pools discovered			304	
Total pool population			500	

NA, nonassociated gas

Gething/Dunlevy play

Play definition

This play includes all gas pools and prospects contained within the Gething and Dunlevy formations in northwest Alberta and northeast British Columbia (Fig. 30). Both conventional and "Deep Basin" gas pools are included in this play.

Geology

The Lower Mannville of northwest Alberta and British Columbia has long been assumed to be stratigraphically continuous, lacking internal unconformities. However, subsurface correlations (Fig. 18) and biostratigraphic data from the different units can be interpreted to show that an erosional unconformity exists between fine grained upper Gething sediments and a sandy basal unit, and in places the unconformity cuts into the underlying Cadomin. Additional unconformities are apparent within the Gething Formation, based on the regional correlations.

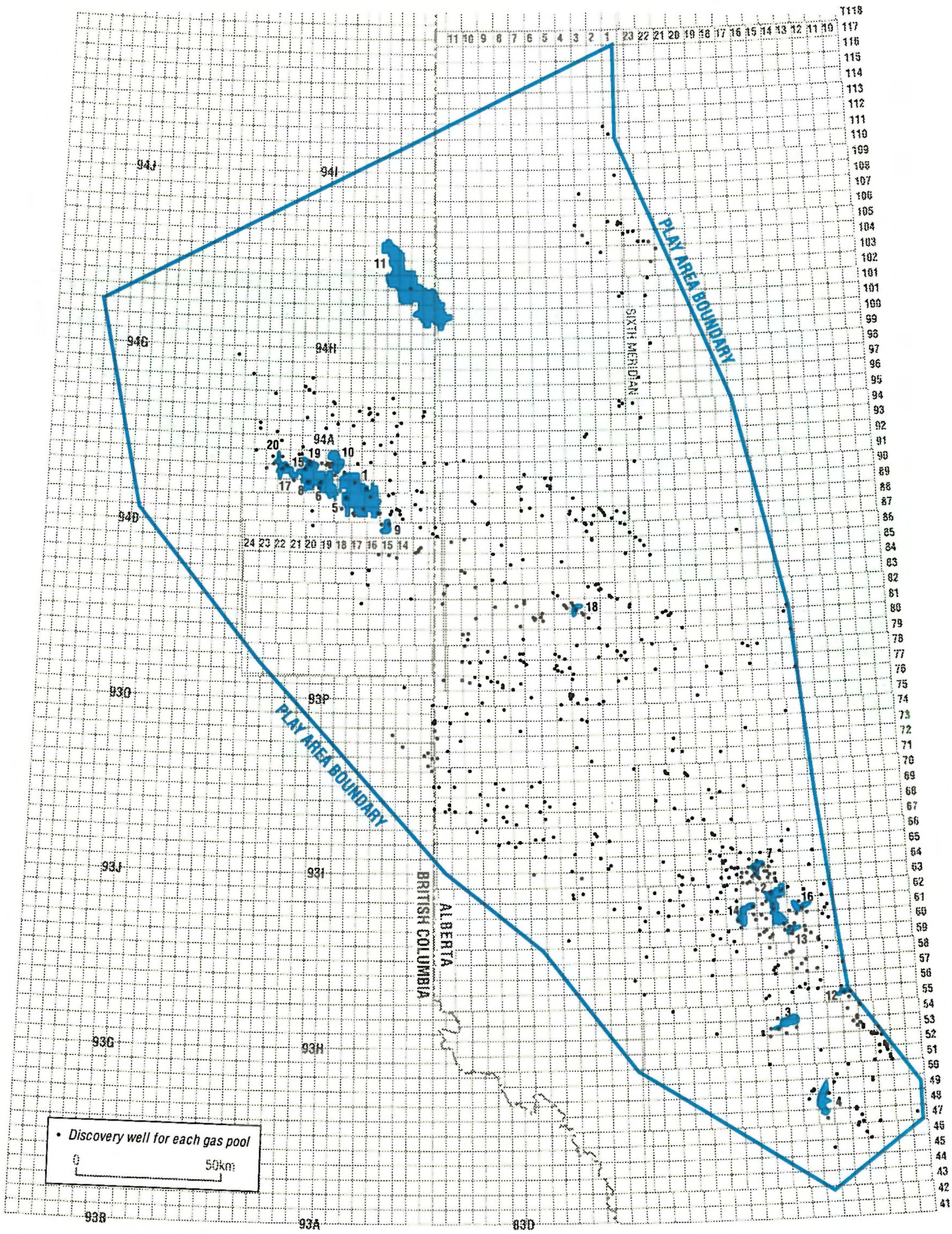
The basal coarse grained portion and the thicker mudstone and coal-dominated portion of the Gething Formation are believed to be dominantly nonmarine. To the north and northeast, some marine shoreface and deltaic sandstones equivalent to the Gething exist. The basal Gething has several sharp-based, fining-upward, sandstone units (based on gamma-ray log patterns), suggesting some form of meandering channel deposition. The fine grained facies contains very thin channel sandstones, but is dominated by floodplain sediments. These are interrupted by much thicker sandstones (up to 20 m), which are believed to be nonmarine fills of incised valleys. Many wells show two or more of these incised valleys, and cross-sections suggest these were localized by repeated small-scale movement on faults of the Peace River Arch. As shown in Figure 13, the thickness of transgressive sediments (Cadomin, Gething, Dunlevy and Bluesky) is affected by the morphology of the basal unconformity, which itself partly reflects Peace River Arch structures in this area. The eastern termination of the lower Gething is controlled by the Fox Creek Escarpment, where the unit onlaps against older sediments. A line of pools (e.g., Kaybob, and Fox Creek) occurs along this edge. Many of the largest pools in this play occur in the Dunlevy Formation in northeast British Columbia. The Dunlevy Formation is equivalent to the upper Gething (Fig. 31).

Exploration history

There have been 693 gas pools discovered in the Gething and Dunlevy formations with a total discovered in-place gas volume of 140 681 x 10^6 m^3 (Figs. 30, 32; Table 3). The earliest discoveries in this play occurred in the 1950s, and have continued through the 1980s. The largest discovered gas pool is the Rigel Dunlevy F pool, which has 13 496 x 10^6 m^3 of gas-in-place and was discovered in 1955. The Gething Pool No. 1 is the second largest gas pool. It is a multi-field pool consisting of the Fox Creek Gething D and H pools, and the Kaybob South Gething H pool. The Gething Pool No. 1 has 8023 x 10^6 m^3 of gas-in-place and was discovered in 1956.

Play potential

The expected potential is 22 151 x 10^6 m^3 of gas-in-place, based on a total pool population of 1000 (Table 3; Fig. 33). Based on this estimate, 14 per cent of the total gas resources for this play remains to be discovered. The largest undiscovered pool is estimated to have 635 x 10^6 m^3 of gas-in-place. The potential for future discoveries is estimated to be good because of the previously unrecognized stratigraphic complexity of the Lower Mannville in the area.



POOLS BY RANK

1 - RIGEL, DUNLEVY 'F'
2 - GETHING POOL 'No. 1'
3 - EDSON, GETHING 'A'
4 - PECO, GETHING 'A'
5 - BUICK CREEK, DUNLEVY 'A'
6 - BUICK CREEK, DUNLEVY 'C'
7 - KAYBOB, GETHING 'K
8 - BUICK CREEK WEST, DUNLEVY 'A'
9 - SIPHON, DUNLEVY 'A'
10 - BUICK CREEK, DUNLEVY 'B'
11 - RING, GETHING 'A'
12 - McLEOD, GETHING 'C'
13 - KAYBOB SOUTH, GETHING 'D'
14 - KAYBOB SOUTH, GETHING 'K'
15 - BUICK CREEK WEST, DUNLEVY 'B'
16 - CHICKADEE, GETHING 'A'
17 - FIREWEED, DUNLEVY 'D'
18 - DUNVEGAN, GETHING 'B'
19 - BUICK CREEK NORTH, DUNLEVY 'A'
20 - FIREWEED, DUNLEVY 'A'

Figure 30. *Play map: northwest Alberta/northeast British Columbia–Gething/Dunlevy play. Pools listed in Table 3.*

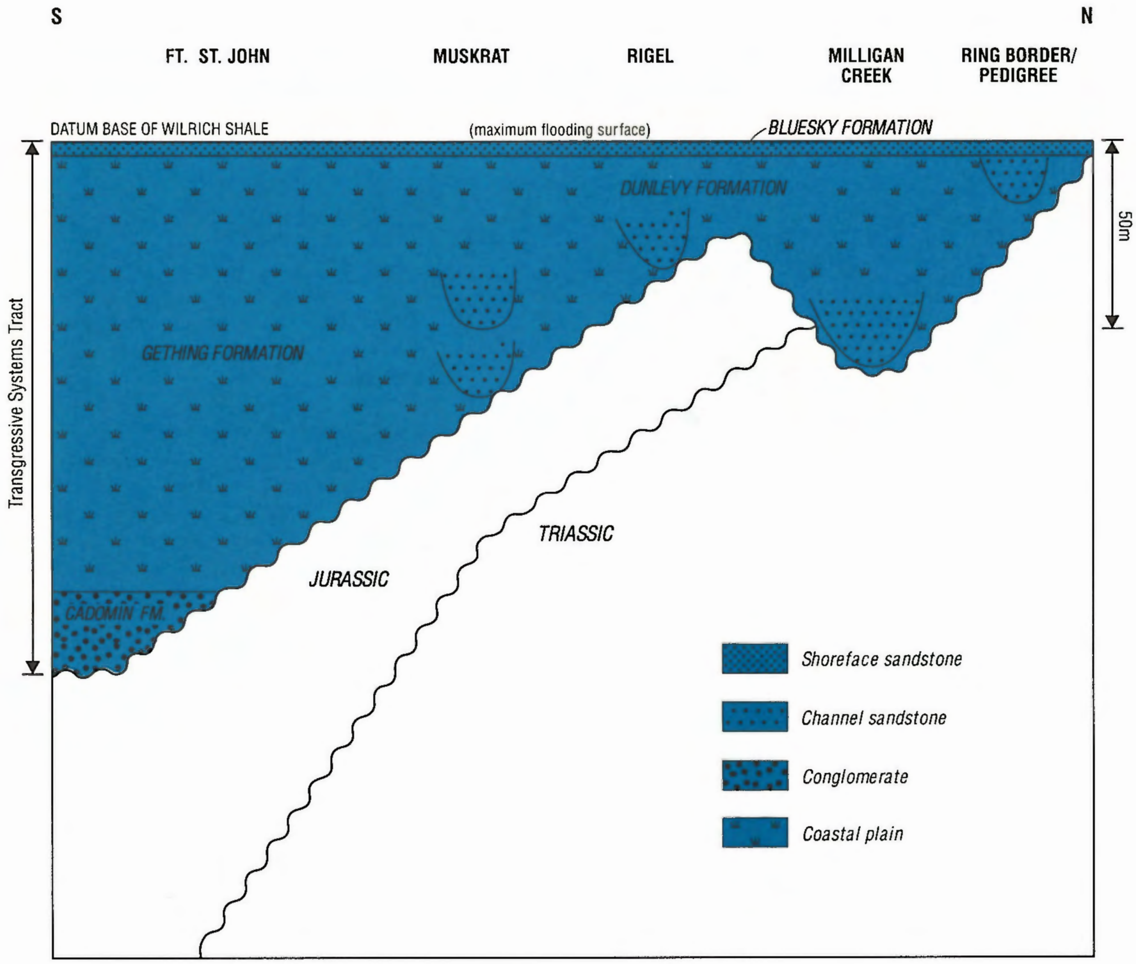


Figure 31. *Stratigraphic cross-section, Gething and Dunlevy formations, northeast British Columbia.*

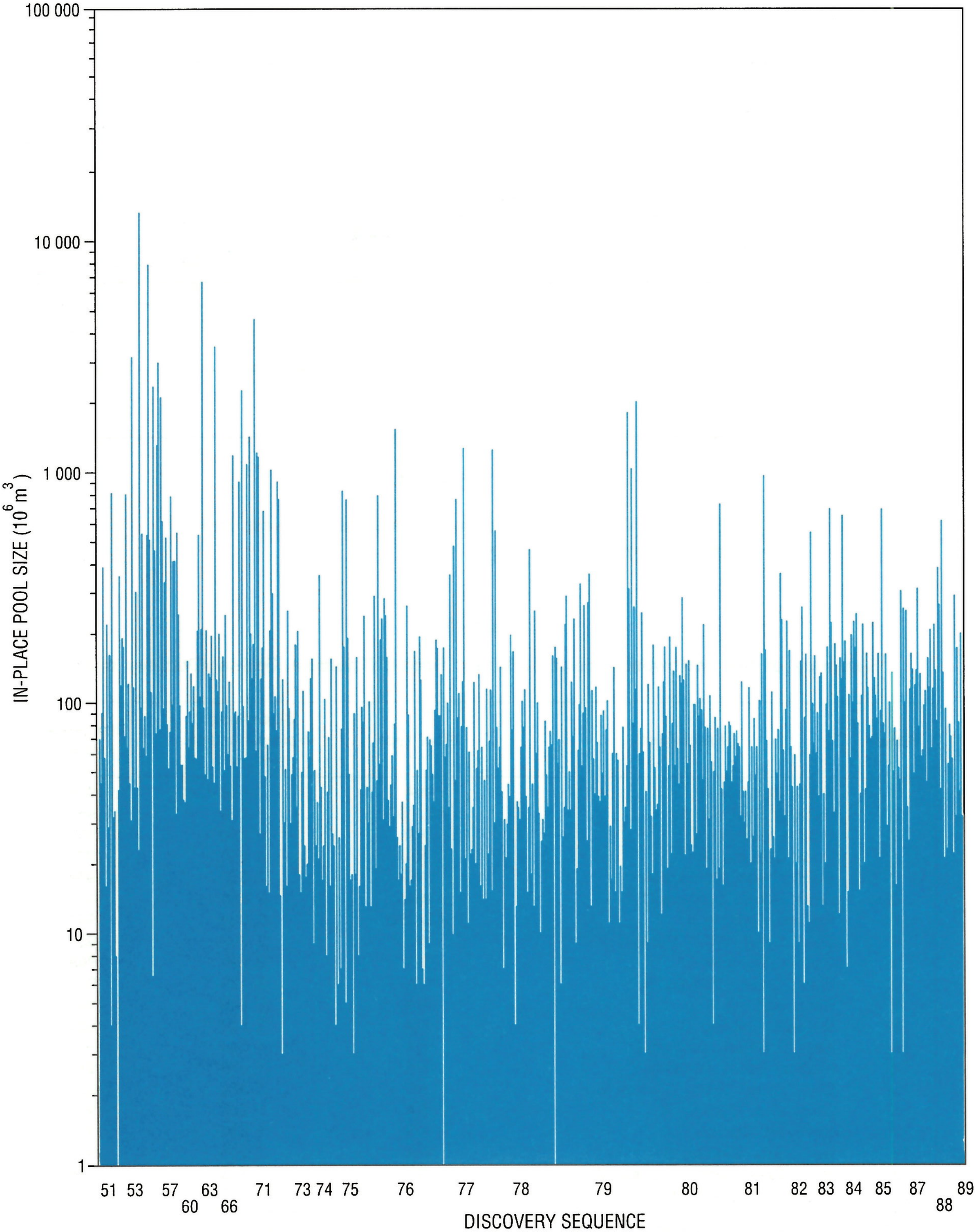


Figure 32. *Discovery sequence: northwest Alberta/northeast British Columbia–Gething/Dunlevy play.*

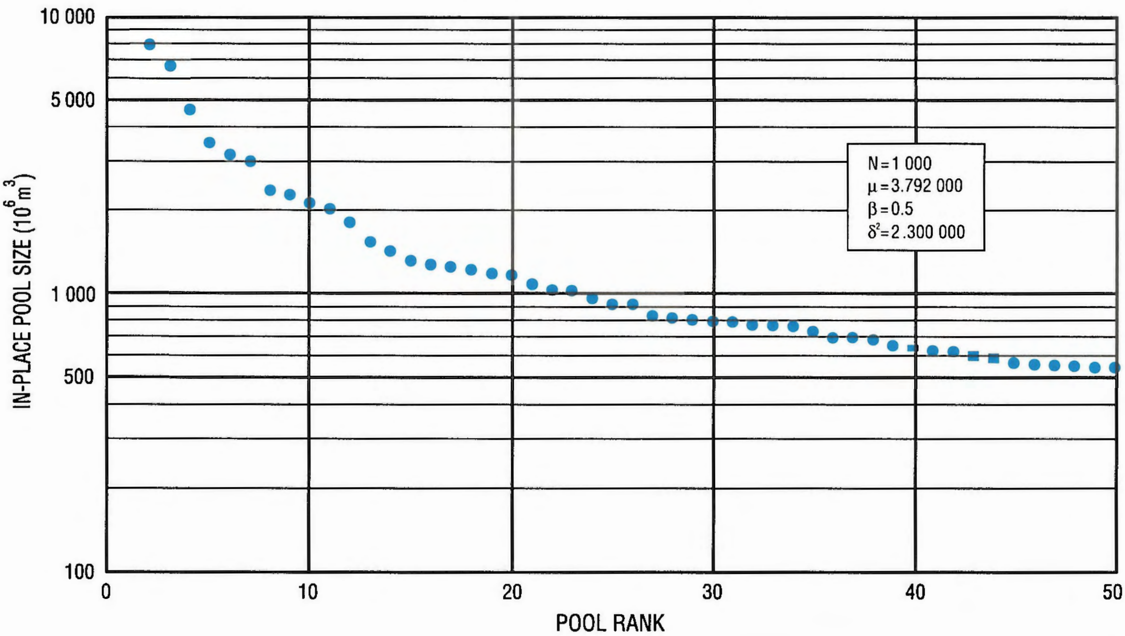


Figure 33. *Pool rank plot: northwest Alberta/northeast British Columbia–Gething/Dunlevy play.*

Table 3

Summary of the northwest Alberta/northeast British Columbia–Gething/Dunlevy play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Rigel, Dunlevy F	NA	13 496	1955
2	Gething Pool No. 1	AG, SG	8 023	1956
3	Edson, Gething A	NA	6 750	1963
4	Peco, Gething A	NA	4 662	1971
5	Buick Creek, Dunlevy A	AG	3 550	1964
6	Buick Creek, Dunlevy C	NA	3 203	1954
7	Kaybob, Gething K	AG, SG	3 034	1957
8	Buick Creek West, Dunlevy A	AG	2 381	1957
9	Siphon, Dunlevy A	NA	2 291	1969
10	Buick Creek, Dunlevy B	NA	2 139	1957
11	Ring, Gething A	NA	2 040	1980
12	McLeod, Gething C	NA	1 823	1980
13	Kaybob South, Gething D	NA	1 548	1976
14	Kaybob South, Gething K	NA	1 438	1971
15	Buick Creek West, Dunlevy B	AG	1 324	1957
16	Chickadee, Gething A	NA	1 280	1977
17	Fireweed, Dunley D	AG	1 260	1978
18	Dunvegan, Gething B	NA	1 226	1971
19	Buick Creek North, Dunlevy A	NA	1 193	1966
20	Fireweed, Dunlevy A	NA	1 175	1971
Initial in-place volume (discovered) (10^6 m^3)			140 681	
Initial in-place volume (potential) (10^6 m^3)			22 151	
Per cent of play resources undiscovered			14	
Total pools discovered			693	
Total pool population			1 000	

NA, nonassociated gas; AG, associated gas; SG, sour gas

Cadomin play

Play definition

This play includes all gas pools and prospects within the Cadomin Formation in the northwest Alberta and northeast British Columbia play area (Fig. 34). Both conventional and "Deep Basin" gas pools are included in this play.

Geology

The Cadomin Formation is the basal Mannville conglomerate in northwestern Alberta and northeast British Columbia. It consists of an eastward-fining wedge of alluvial fan and braided river conglomerate (Varley, 1984) shed from the overthrust belt and onlapping against the Fox Creek Escarpment. In the subsurface, its southern extent is restricted by the thrust front. Many workers consider the Cadomin to be stratigraphically continuous with the overlying parts of the Mannville, but at least one unconformity divides the section, and recent palynological dating suggests that it is considerably older than the remainder of the Mannville.

Because the Cadomin is essentially a sheet of coarse grained sediment, stratigraphic traps due to lateral facies changes are absent. Two distinct types of petroleum traps occur: 1) conventional structural traps, such as drape over Devonian reefs (e.g., Gold Creek field), and stratigraphic traps developed at the updip termination of the Cadomin along the Fox Creek Escarpment (e.g., Kaybob field); and 2) the so-called "Deep Basin" trap (discussed previously), in which the Cadomin has undergone significant permeability reduction by cementation and is saturated by underpressured gas. Updip, the gas zone grades through a pressure transition into more permeable water-saturated sediment (Gies, 1984; Varley, 1984). Most of the largest Cadomin fields, such as Elmworth, Sinclair, and the several Wapiti fields, are "Deep Basin"-type traps.

Exploration history

Several Cadomin fields associated with drape over Devonian carbonate structures were discovered in the 1960s in exploration of west-central Alberta. In the late 1970s and 1980s, exploration concentrated on "Deep Basin"-type accumulations. There have been 178 pools discovered in the Cadomin Formation, with a total discovered gas resource of 45 691 x 10^6 m^3 (Figs. 34, 35; Table 4). The largest discovered pool is the Cadomin Pool No. 1, which is a multi-field pool consisting of the Elmworth and Sinclair Cadomin A pools. It has 12 522 x 10^6 m^3 of gas-in-place and was discovered in 1977. This pool has been used as an example of a "Deep Basin" trap by Varley (1984) and Gies (1984).

Play potential

The expected potential is estimated to be 100 010 x 10^6 m^3 of gas-in-place. This indicates that 69 per cent of the total gas resources in this play remains to be discovered. The total pool population is predicted to be 900 pools, with the largest undiscovered pool estimated to have 10 856 x 10^6 m^3 of gas-in-place (Table 4; Fig. 36). Future exploration targets will probably be identified from detailed studies of the stratigraphy of the Cadomin Formation and the overlying Gething Formation. At least one unconformity has been recognized between the Cadomin and overlying basal Gething and more detailed work on the stratigraphy of these two units may lead to future exploration possibilities.

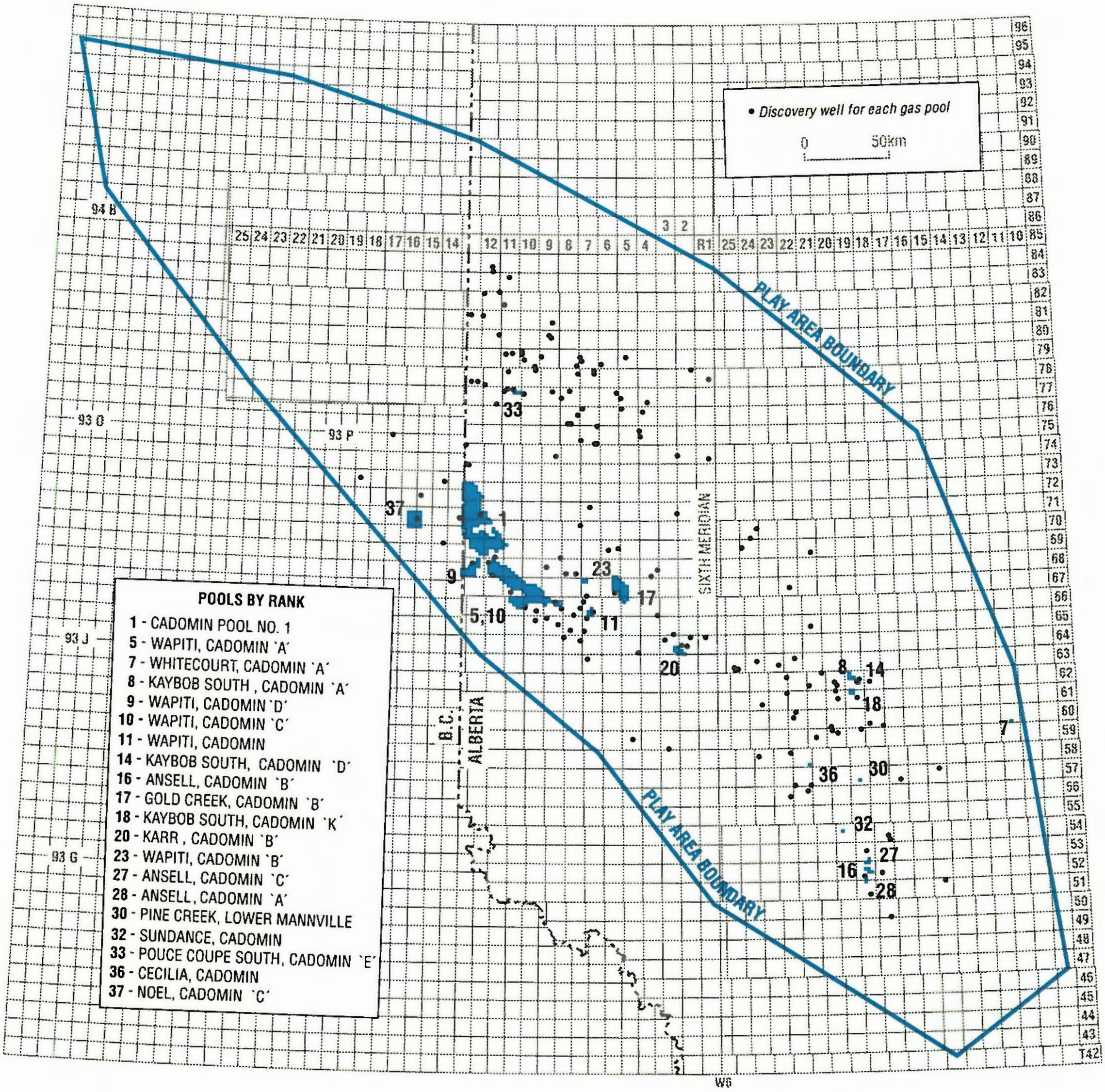


Figure 34. *Play map: northwest Alberta/northeast British Columbia–Cadomin play. Pools listed in Table 4.*

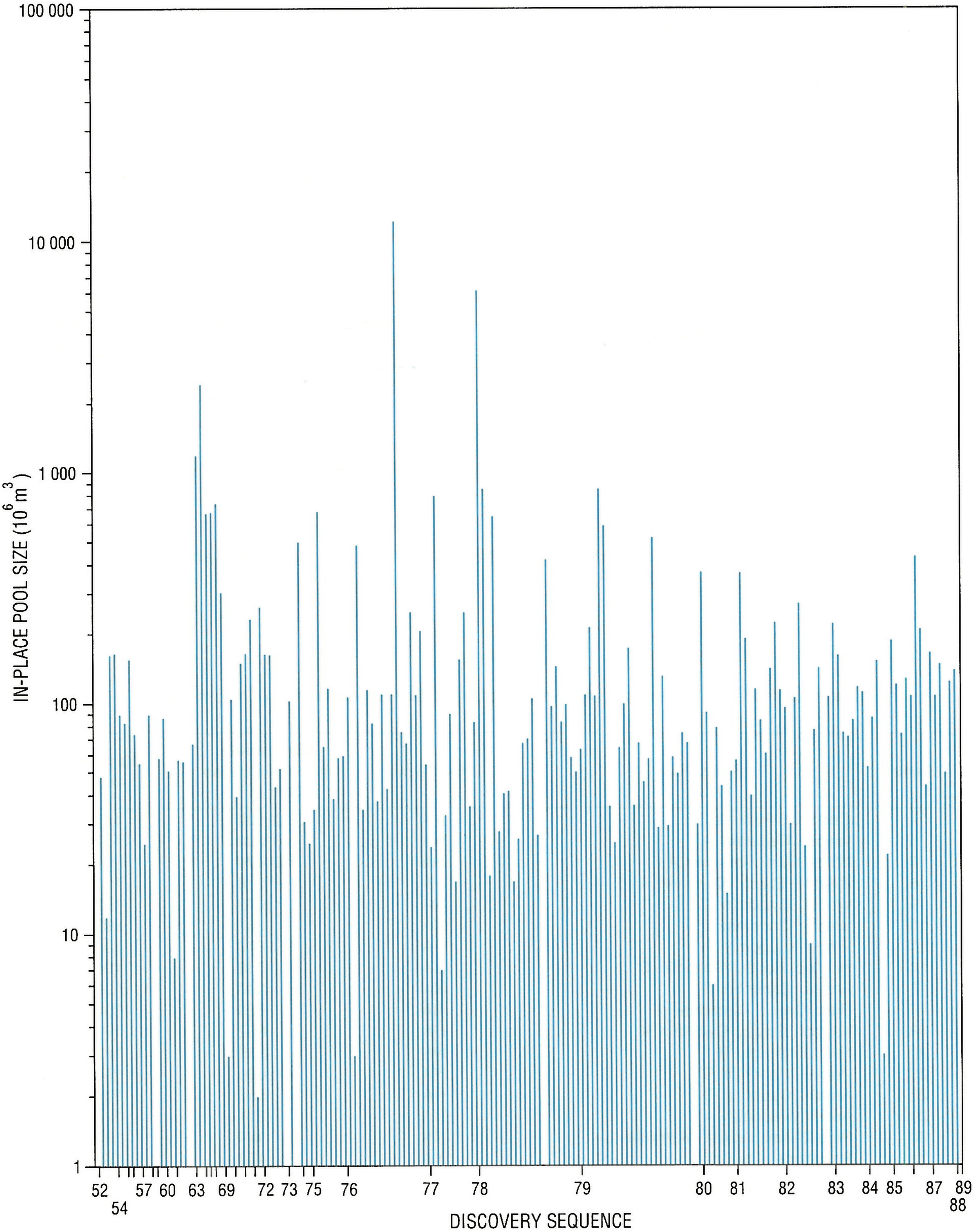


Figure 35. *Discovery sequence: northwest Alberta/northeast British Columbia–Cadomin play.*

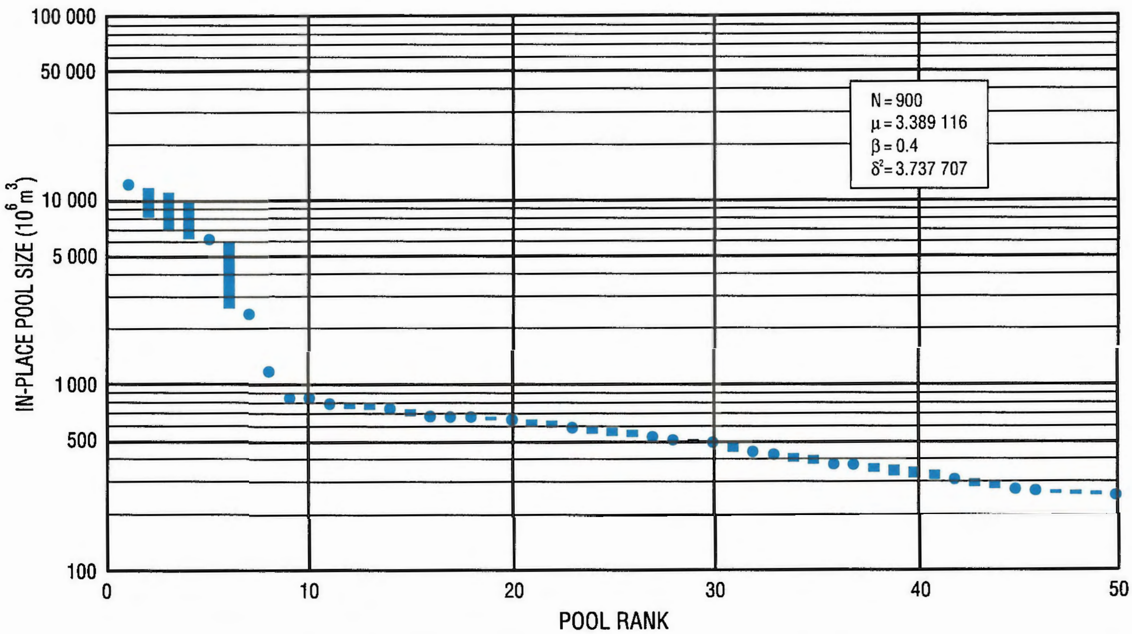


Figure 36. *Pool rank plot: northwest Alberta/northeast British Columbia–Cadomin play.*

Table 4

Summary of the northwest Alberta/northeast British Columbia–Cadomin play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Cadomin Pool No. 1	NA	12 522	1977
5	Wapiti, Cadomin A	NA	6 303	1978
7	Whitecourt, Cadomin A	NA	2 476	1963
8	Kaybob South, Cadomin A	NA	1 216	1961
9	Wapiti, Cadomin D	NA	868	1979
10	Wapiti, Cadomin C	NA	867	1980
11	Wapiti, Cadomin	NA	810	1978
14	Kaybob South, Cadomin D	NA	753	1967
16	Ansell, Cadomin B	NA	693	1976
17	Gold Creek, Cadomin B	NA	689	1965
18	Kaybob South, Cadomin K	NA	682	1963
20	Karr, Cadomin B	NA	659	1979
23	Wapiti, Cadomin B	NA	600	1980
27	Ansell, Cadomin C	NA	532	1980
28	Ansell, Cadomin A	NA	511	1974
30	Pine Creek, Lower Mannville	NA	494	1977
32	Sundance, Cadomin	NA	438	1987
33	Pouce Coupe South, Cadomin E	NA	427	1979
36	Cecilia, Cadomin	NA	376	1980
37	Noel, Cadomin C	NA	373	1982
Initial in-place volume (discovered) (10^6 m^3)			45 691	
Initial in-place volume (potential) (10^6 m^3)			100 010	
Per cent of play resources undiscovered			69	
Total pools discovered			178	
Total pool population			900	

NA, nonassociated gas

Athabasca

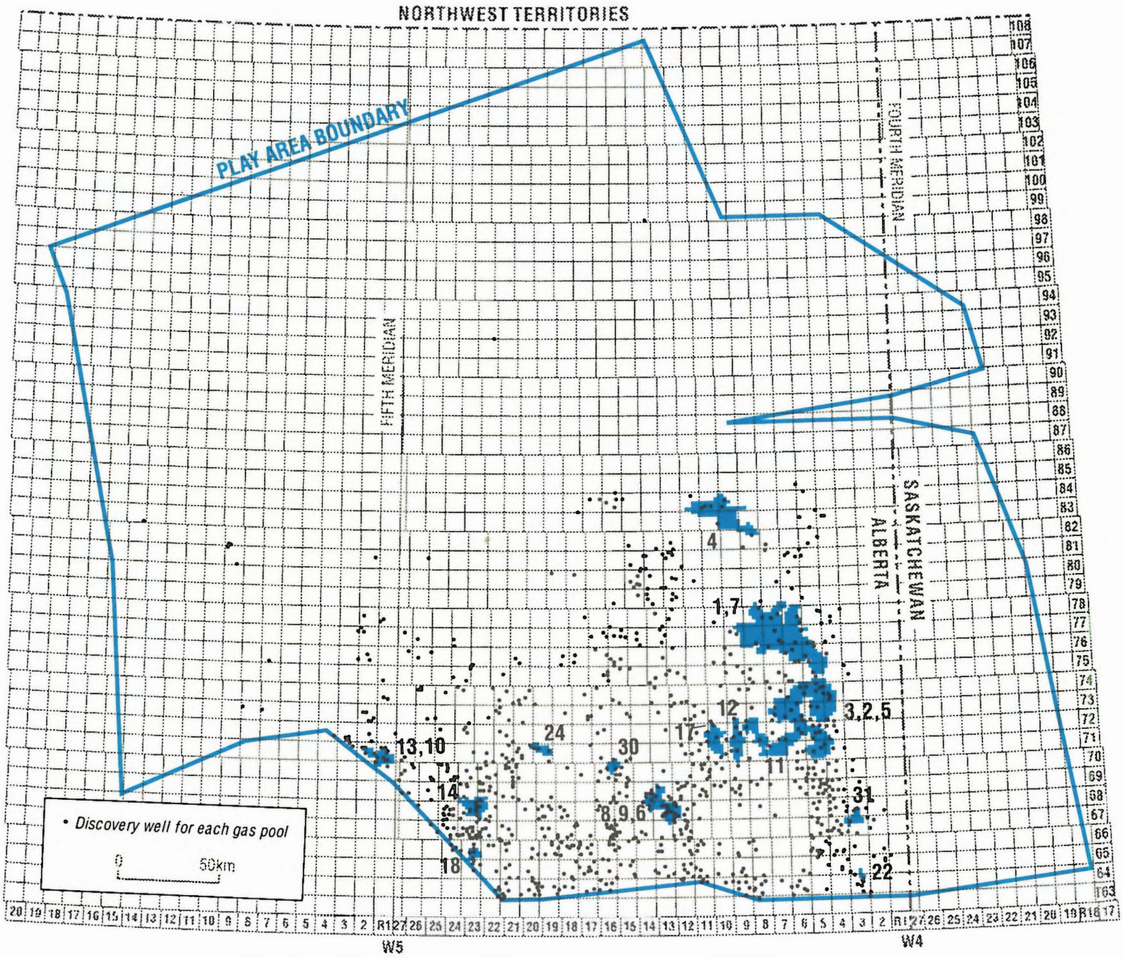
Grand Rapids/Clearwater play

Play definition

This play includes all gas-bearing pools and prospects within the Grand Rapids and Clearwater formations in the Athabasca play area (Fig. 37).

Geology

The Clearwater Formation in the Athabasca play area consists of a series of interbedded nearshore marine sandstones and shales that are part of the overall northward prograding Upper Mannville Group. The Clearwater Formation has been studied in detail in the Leismer field by Maher (1989). Maher divides the Clearwater Formation into four sandstone units (A, B, C, D) which he interpreted to be amalgamated, nearshore bar complexes. These nearshore bar complexes could be reinterpreted as a series of lowstand shoreface sandstones derived from incised valleys cutting through the Lloydminster to Sparky successions of the Lloydminster area. The occurence of hydrocarbon reservoirs in the Clearwater sandstones occurs in stratigraphically younger units from south to north (seaward). The southernmost, and oldest, Clearwater D sand is the reservoir for the heavy oil



POOLS BY RANK

1 - LEISMER, CLEARWATER 'A'
2 - KIRBY, UPPER MANNVILLE 'A'
3 - KIRBY, UPPER MANNVILLE 'C'
4 - HANGINGSTONE, UPPER MANNVILLE 'A'
5 - KIRBY, UPPER MANNVILLE 'D'
6 - TWEEDIE, GRAND RAPIDS 'D'
7 - KIRBY, UPPER MANNVILLE 'K'
8 - TWEEDIE, GLAUCONITE 'B'
9 - TWEEDIE, GLAUCONITE 'A'
10 - DECRENE, CLEARWATER 'A'
11 - GRIST, GRAND RAPIDS 'A'
12 - IPIATIK, GRAND RAPIDS 'A'
13 - DECRENE, CLEARWATER 'B'
14 - BAPTISTE, MANNVILLE 'G'
17 - IPIATIK, GRAND RAPIDS 'B'
18 - ATHABASCA, GRAND RAPIDS 'B'
22 - ETHEL LAKE GRAND RAPIDS 'A'
24 - CALLING LAKE WEST, UPPER MANNVILLE 'A'
30 - CHARRON, GRAND RAPIDS 'B'
31 - MOORE, GRAND RAPIDS 'A'

***Figure 37.** Play map: Athabasca–Grand Rapids/Clearwater play. Pools listed in Table 5.*

deposits of Cold Lake, the C sand produces at Kirby, the B sand produces at Leismer, and in the north, the youngest, A sand, produces at Hangingstone (Figs. 38, 39).

The overlying Grand Rapids Formation consists of thick sandstones (up to 60 m) deposited by northwest-prograding shorefaces. They are separated from the shoreline deposits of the Lloydminster-area by a wide area of restricted-marine deposits. Regional correlations show that the unit is the distal equivalent of the Colony, McLaren, and Waseca formations and can be interpreted as the lowstand deposits discharged from the numerous valleys cutting through these units. In the past, the Grand Rapids Formation has been subdivided into three laterally extensive units, each of which is a composite of many individual sandstone bodies. These comprise a very complex series of lowstand shoreface deposits, onlapping each other laterally, clinoforming distally, and grading into shales to the north. Many shorefaces are cut by valleys discharging sand farther seaward into more distal shorefaces. The sand bodies are concentrated into a relatively small area in northeastern Alberta because of compactional effects over topography on the sub-Cretaceous unconformity and solution of Devonian salt. These features created a slightly higher local rate of subsidence during Mannville deposition, thereby concentrating the discharge points of the lowstand sandstones. Because of this concentration, erosional amalgamation occurred, creating thicker and more laterally continuous sandstones in places. Gas traps have a stratigraphic control, due to the sandstones being separated by thin transgressive shale interbeds. Clearwater sandstones tend to be more isolated, forming stratigraphic traps. Salt solution has also affected Clearwater and Grand Rapids reservoirs, in places causing structural closure and trapping in some of the largest gas fields (e.g., Kirby).

Exploration history

Although some pools in this play were discovered in the 1940s, increased drilling in the late 1970s resulted in the discovery of many of the largest fields. The largest pool discovered in the play is the Leismer Clearwater A pool. The pool was discovered in 1974 and has an initial gas-in-place volume of 24 291 x 10^6 m^3. The Leismer Clearwater A pool produces from the Clearwater B sandstone (Maher, 1989). The Clearwater B sandstone is a poorly consolidated, moderately well sorted, fine grained, feldspathic litharenite. The trapping mechanism in the Leismer Clearwater A pool is a result of two factors: 1) the basinward stratigraphic pinchout of the Clearwater B sandstone in a northerly direction, and 2) an easterly structural dip reversal of the Lower Cretaceous section due to structural collapse caused by solution of the underlying Devonian Elk Point salt (Maher, 1989). The Clearwater B sandstone is up to 30 m thick, with an average net pay of 4.6 m (Maher, 1989). The total number of pools that have been discovered in the Athabasca-Grand Rapids/Clearwater play is 1275, with a total discovered gas-in-place volume of 87 535 x 10^6 m^3 (Figs. 37, 40; Table 5).

Play potential

The estimated expected potential for the Athabasca–Grand Rapids/Clearwater play is 55 060 x 10^6 m^3 of gas-in-place, based on a total pool population of 2920 (Table 5; Fig. 41). This estimate indicates that 39 per cent of the total gas resources for the Athabasca-Grand Rapids/Clearwater play remains to be discovered. The largest undiscovered pool is estimated to contain 712 x 10^6 m^3 of gas-in-place.

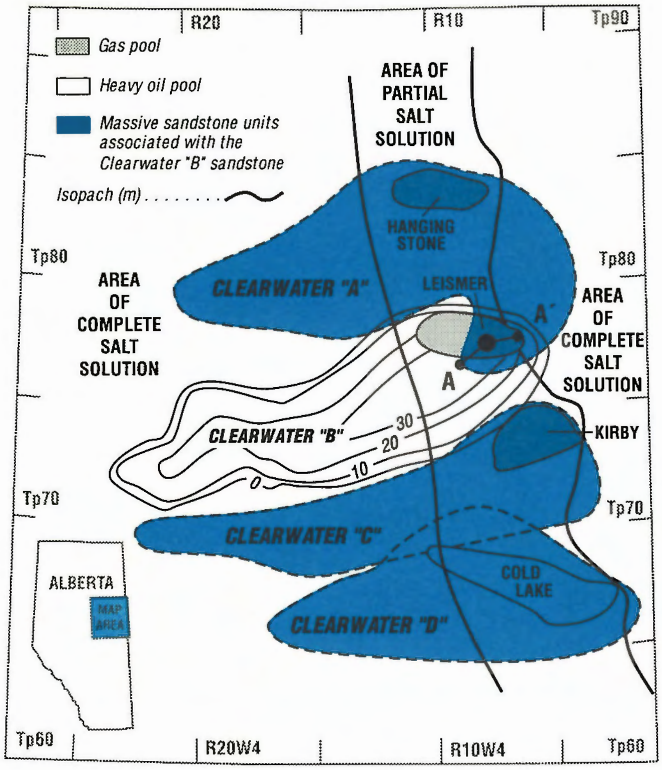


Figure 38. Regional trend of the Clearwater sandstones and associated gas and heavy oil pools, Athabasca area, northeast Alberta (modified from Maher, 1989).

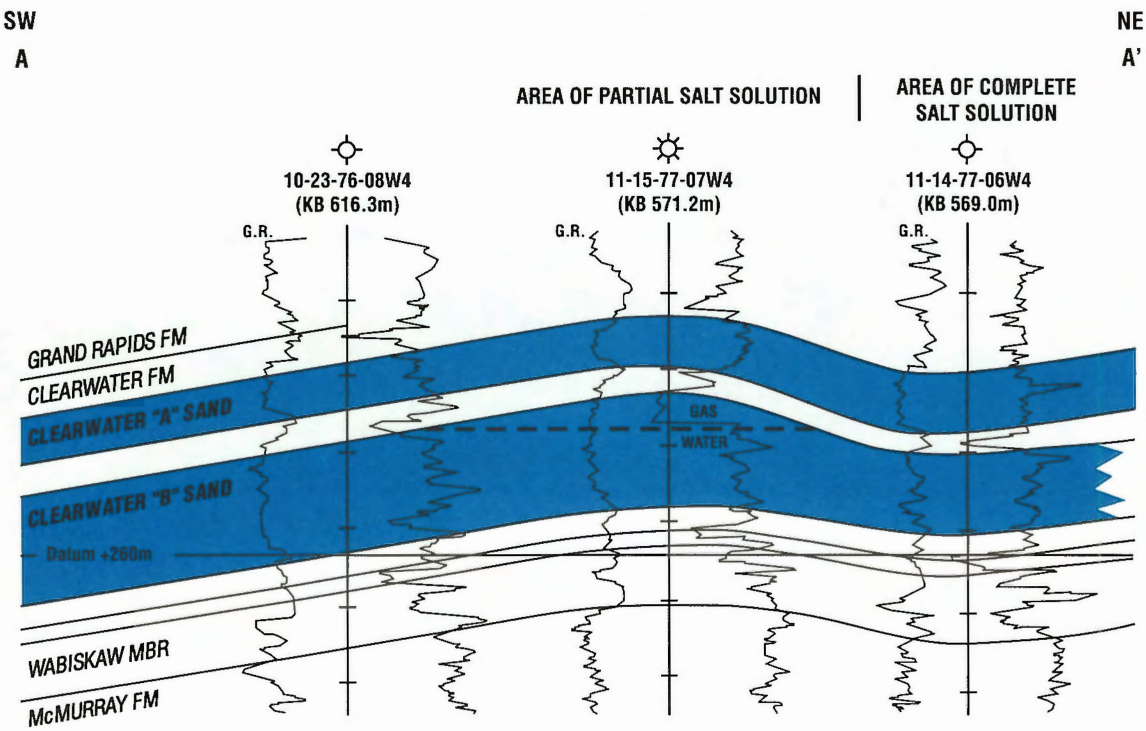


Figure 39. Structural cross-section A–A" (see Fig. 38) across the Leismer Field (modified from Maher, 1989).

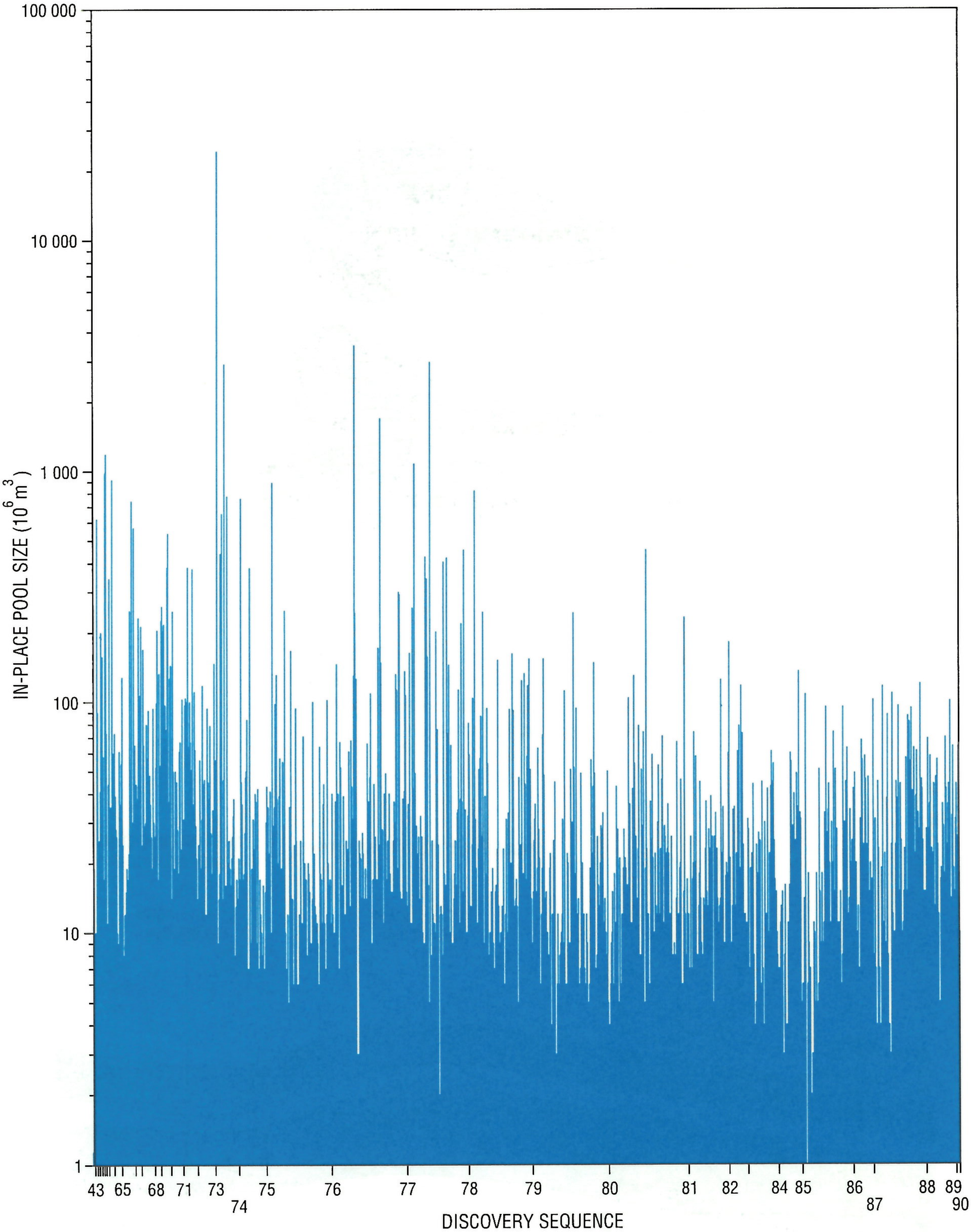


Figure 40. *Discovery sequence: Athabasca–Grand Rapids/Clearwater play.*

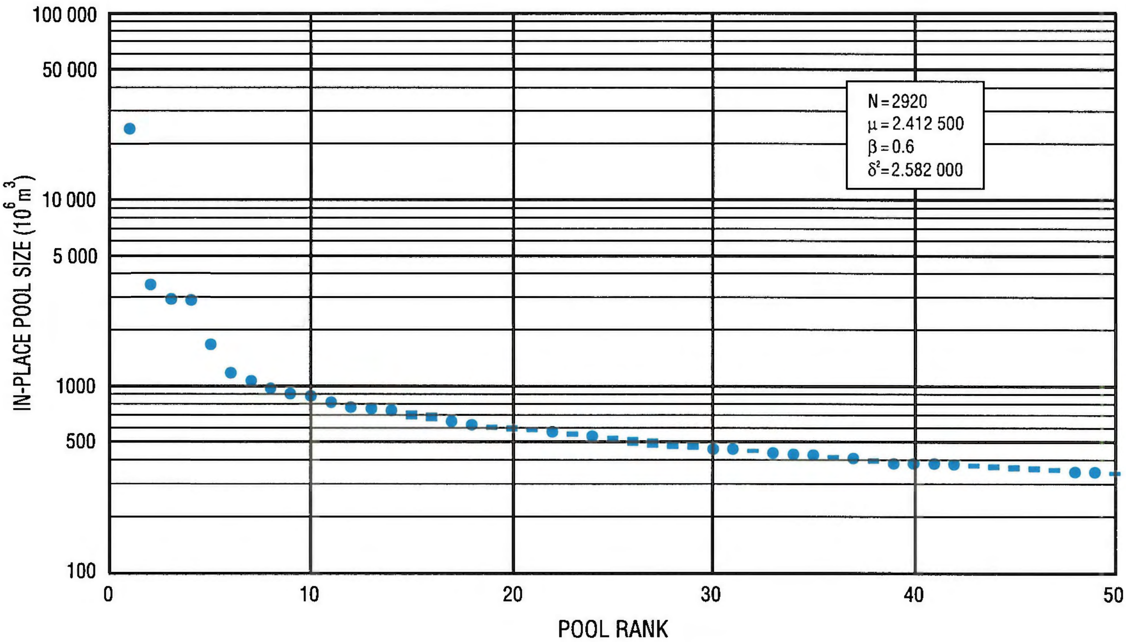


Figure 41. *Pool rank plot: Athabasca–Grand Rapids/Clearwater play.*

Table 5

Summary of the Athabasca-Grand Rapids/Clearwater play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Leismer, Clearwater A	NA	24 291	1974
2	Kirby, Upper Mannville A	NA	3 508	1977
3	Kirby, Upper Mannville C	NA	2 982	1978
4	Hangingstone, Upper Mannville A	NA	2 915	1974
5	Kirby, Upper Mannville D	NA	1 698	1977
6	Tweedie, Grand Rapids D	NA	1 184	1961
7	Kirby, Upper Mannville K	NA	1 079	1978
8	Tweedie, Glauconite B	NA	983	1961
9	Tweedie, Glauconite A	NA	919	1962
10	Decrene, Clearwater A	NA	892	1976
11	Grist, Grand Rapids A	NA	824	1979
12	Ipiatik, Grankd Rapids A	NA	778	1974
13	Decrene, Clearwater B	NA	761	1975
14	Baptiste, Mannville G	NA	741	1966
17	Ipiatik, Grand Rapids B	NA	653	1974
18	Athabasca, Grand Rapids B	NA	620	1952
22	Ethel Lake, Grand Rapids A	NA	569	1966
24	Calling Lake West, Upper Mannville A	NA	538	1970
30	Charron, Grand Rapids B	NA	457	1978
31	Moore, Grand Rapids A	NA	457	1981
Initial in-place volume (discovered) (10^6 m^3)			87 535	
Initial in-place volume (potential) (10^6 m^3)			55 060	
Per cent of play resources undiscovered			39	
Total pools discovered			1 275	
Total pool population			2 920	

NA, nonassociated gas

Wabiskaw play

Play definition

This play includes all gas pools and prospects contained in the Wabiskaw Formation in the Athabasca play area (Fig. 42).

Geology

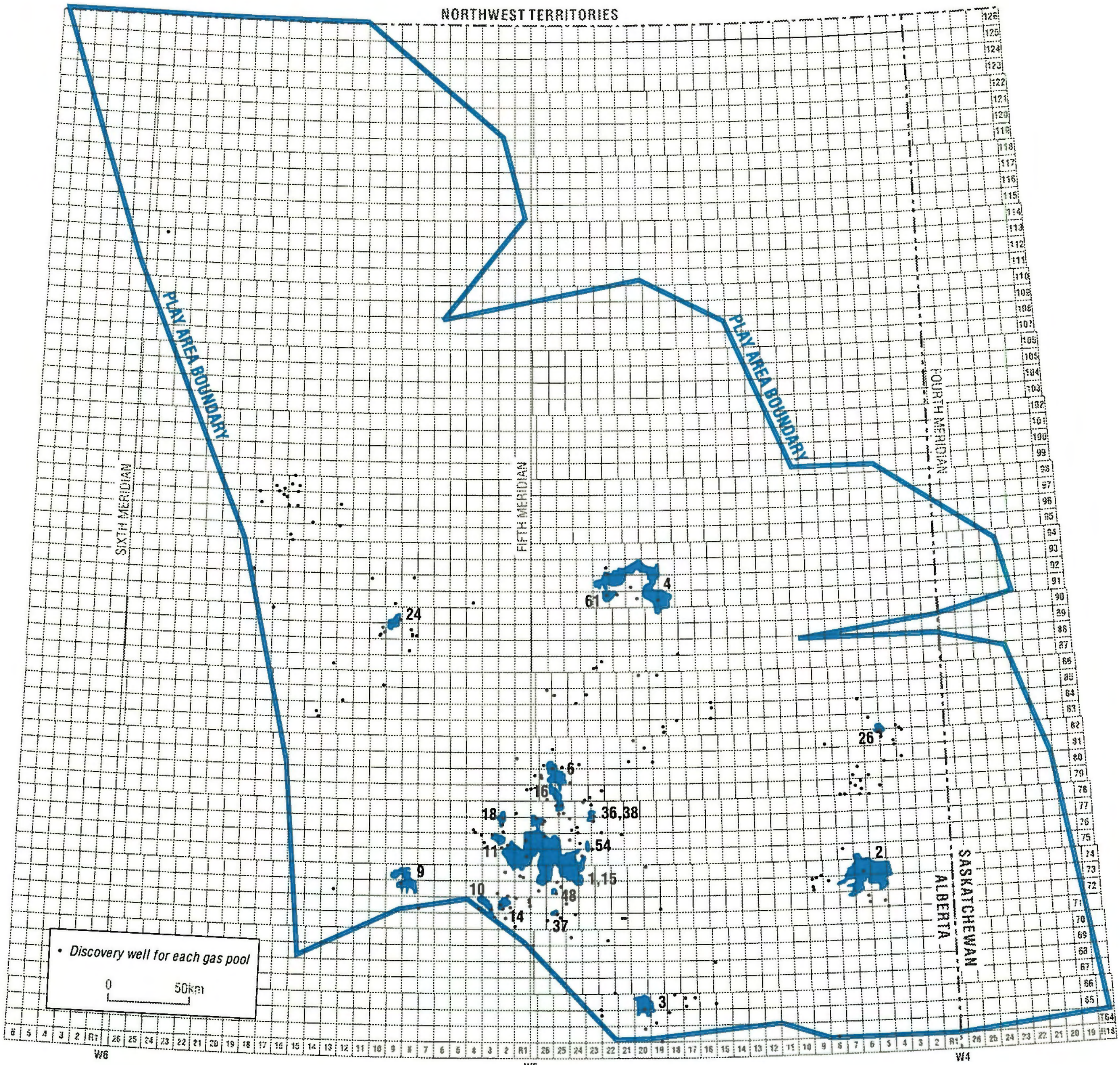
The Wabiskaw Formation has been studied intensively because it is an important bitumen reservoir (Strobl et al., 1993). It consists of a set of shoreface sandstones overlying the McMurray Formation, generated during the Boreal transgression from the north. It is equivalent to the Bluesky Formation, which occupies the same stratigraphic position in the west, and has similar sedimentological characteristics. In many places, the shorefaces are cut by valley-fills which may consist either of sandstone or mudstone. Many traps are stratigraphic, but the largest ones have structural closure (e.g., Marten Hills) created by drape over the topography on the basal unconformity. As mapped by Strobl et al. (1993), a number of large gas fields are controlled by the Wainwright Ridge, an east-trending high on the basal unconformity. In other places, salt solution creates structural closure.

Exploration history

The total number of gas pools discovered in the Athabasca-Wabiskaw play is 219 and the total gas-in-place is 53 957 x 10^6 m^3 (Figs. 42, 43; Table 6). The Marten Hills Wabiskaw A pool is the largest gas pool discovered in the play, with 23 553 x 10^6 m^3 of gas-in-place. The Marten Hills pool was discovered in 1960 in a well drilled for a Leduc Formation seismic anomaly. The present structural closure in the Marten Hills Wabiskaw A pool is a result of differential compaction of the Wabiskaw Formation over a high on the Wabamun Group.

Play potential

The estimated expected play potential for the Athabasca-Wabiskaw play is 21 776 x 10^6 m^3 of gas-in-place, based on a total pool population of 700. This estimate indicates that 29 per cent of the total gas resources for the play remains to be discovered (Table 6; Fig. 44). The largest undiscovered gas pool is estimated to have 1346 x 10^6 m^3 of gas-in-place.



POOLS BY RANK

1 - MARTEN HILLS, WABISKAW `A'	9 - KIRBY, UPPER MANNVILLE `J'	16 - PELICAN, WABISKAW `A'	37 - SMITH, WABISKAW
2 - KIRBY, UPPER MANNVILLE `I'	10 - MITSUE, WABISKAW `D'	18 - DOUCETTE, WABISKAW `A'	38 - DRIFTWOOD, WABISKAW
3 - FLAT, WABISKAW `A'	11 - MARTEN HILLS, WABISKAW `C'	24 - RED EARTH, BLUESKY `A'	48 - MARTEN HILLS, WABISKAW
4 - LIEGE, WABISKAW `A'	14 - SPUR, WABISKAW `A'	26 - NEWBY, WABISKAW `A'	54 - DROWNED, WABISKAW `A'
6 - HOOLE, WABISKAW `A'	15 - McMULLEN, WABISKAW `A'	36 - DRIFTWOOD, WABISKAW	61 - LEIGE, WABISKAW `D'

Figure 42. *Play map: Athabasca–Wabiskaw play. Pools lsited in Table 6.*

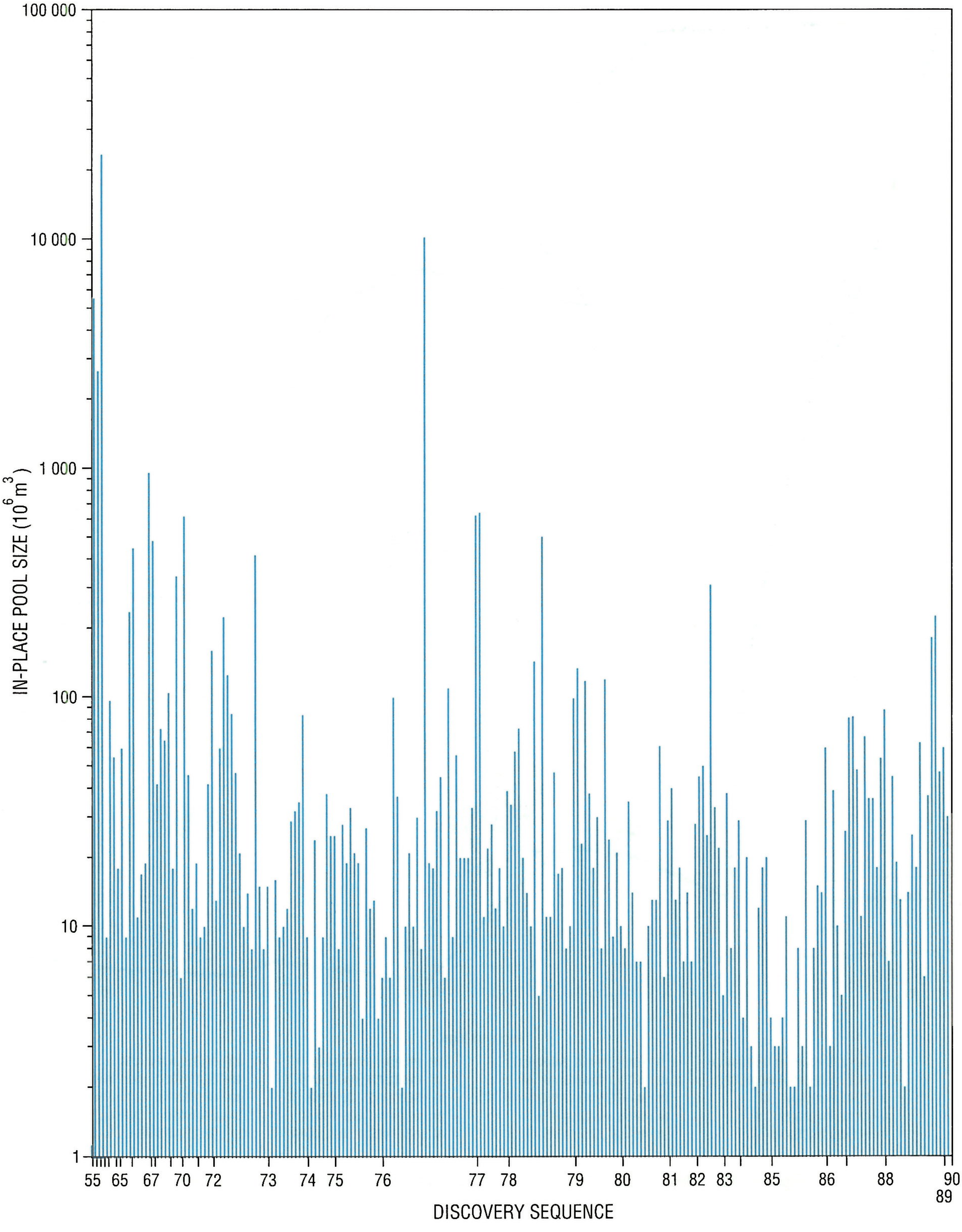


Figure 43. Discovery sequence: Athabasca–Wabiskaw play.

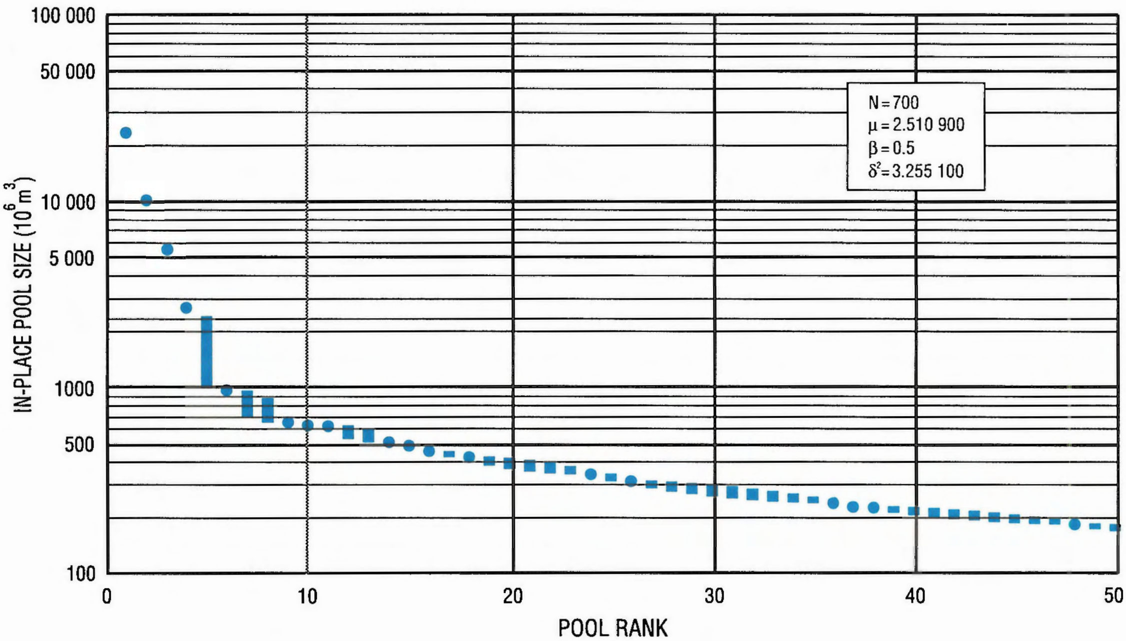


***Figure 44.** Pool rank plot: Athabasca–Wabiskaw play.*

Table 6

Summary of the Athabasca-Wabiskaw play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Marten Hills, Wabiskaw A	NA	23 553	1960
2	Kirby, Upper Mannville I	NA	10 252	1977
3	Flat, Wabiskaw A	NA	5 564	1955
4	Liege, Wabiskaw A	NA	2 674	1959
6	Hoole, Wabiskaw A	NA	963	1967
9	Kirby, Upper Mannville J	NA	644	1978
10	Mitsue, Wabiskaw D	NA	627	1977
11	Marten Hills, Wabiskaw C	NA	622	1971
14	Spur, Wabiskaw A	NA	506	1979
15	McMullen, Wabiskaw A	NA	486	1968
16	Pelican, Wabiskaw A	NA	450	1967
18	Doucette, Wabiskaw A	NA	420	1973
24	Red Earth, Bluesky A	NA	339	1970
26	Newby, Wabiskaw A	NA	310	1983
36	Driftwood, Wabiskaw	NA	237	1966
37	Smith, Wabiskaw	NA	226	1989
38	Driftwood, Wabiskaw	NA	225	1973
48	Marten Hills, Wabiskaw	NA	182	1989
54	Drowned, Wabiskaw A	NA	161	1972
61	Leige, Wabiskaw D	NA	144	1979
Initial in-place volume (discovered) (10^6 m^3)			53 957	
Initial in-place volume (potential) (10^6 m^3)			21 776	
Per cent of play resources undiscovered			29	
Total pools discovered			219	
Total pool population			700	

NA, nonassociated gas

McMurray play

Play definition

This play includes all gas pools and prospects that are contained within the McMurray Formation in the Athabasca play area (Fig. 45).

Geology

Because the McMurray Formation acts as the reservoir for the Athabasca oil sands, it has been the object of several studies (Flach, 1984; Flach and Mossop, 1985; Strobl et al., 1993). The gas distribution is related to the bitumen, in that it most commonly occurs as a cap above the degraded oil in a sandstone body. This implies that the gas was trapped when the oil was fluid, before the degradation of the oil was complete. Some fraction of the gas may have resulted from the degradation itself.

The McMurray Formation was deposited in the eastern part of the basin (Fig. 13) where northward-draining valleys cut on the basal unconformity encounter a broad depositional area. The original drainage system influenced the distribution of McMurray sands; they tend to be concentrated over the lows. The Lower McMurray may be considerably older than the remainder of the unit, as has been recognized by several authors in the past (Carrigy, 1973; Burden, 1984). The major reservoirs occur in the Middle and Upper McMurray, and comprise very large valley-fills (cut down from the top of the unit) with estuarine channel and overbank deposits in the north, grading to more fluvial deposits in the south.

The trapping mechanism for the gas is similar to other parts of the Mannville, with both structural and stratigraphic traps occurring. However, the most common mechanism by far, is onlap (also including some drape effects) against the Wainwright ridge on the basal unconformity (e.g., Marten Hills). The gas sands mapped by Strobl et al. (1993) fall primarily along this ridge. Some fields are stratigraphic traps caused by the termination of a porous zone in the Lower McMurray (Duncan field).

Exploration history

A total of 565 gas pools has been discovered in the Athabasca-McMurray play, with a total in-place gas volume of 45 450 x 10^6 m^3 (Figs. 45, 46; Table 7). The Chard McMurray B pool is the largest discovered gas pool in the play. It was discovered in 1957 and has 4252 x 10^6 m^3 of gas-in-place.

Play potential

The expected play potential is estimated to be 13 413 x 10^6 m^3 of gas-in-place, based on a total pool population of 1100 (Table 7; Fig. 47). The largest undiscovered gas pool is estimated to have 408 x 10^6 m^3 of gas-in-place. Based on this estimate, 23 per cent of the total gas resources of this play remains to be discovered.

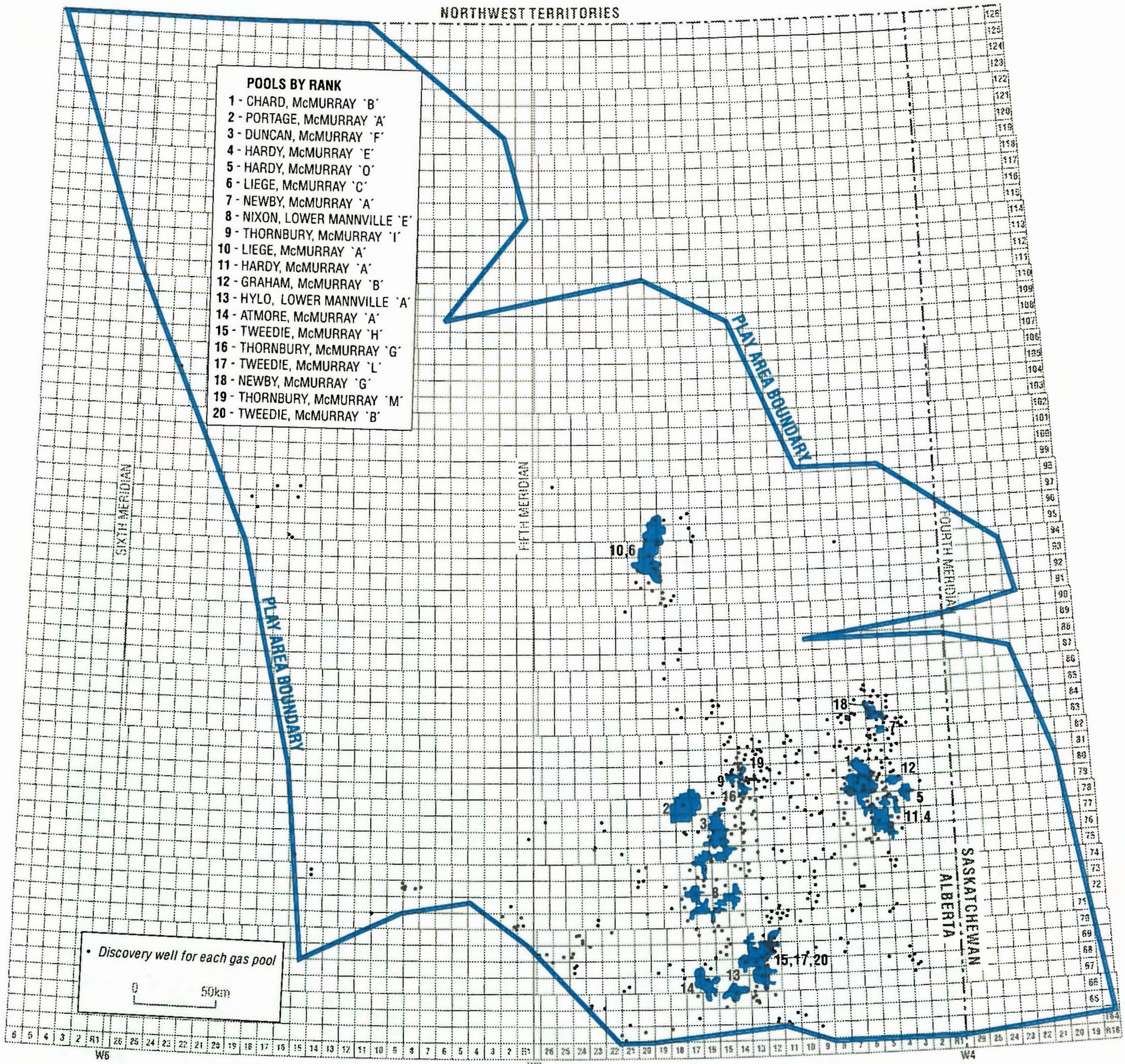


Figure 45. Play map: Athabasca–McMurray play. Pools listed in Table 7.

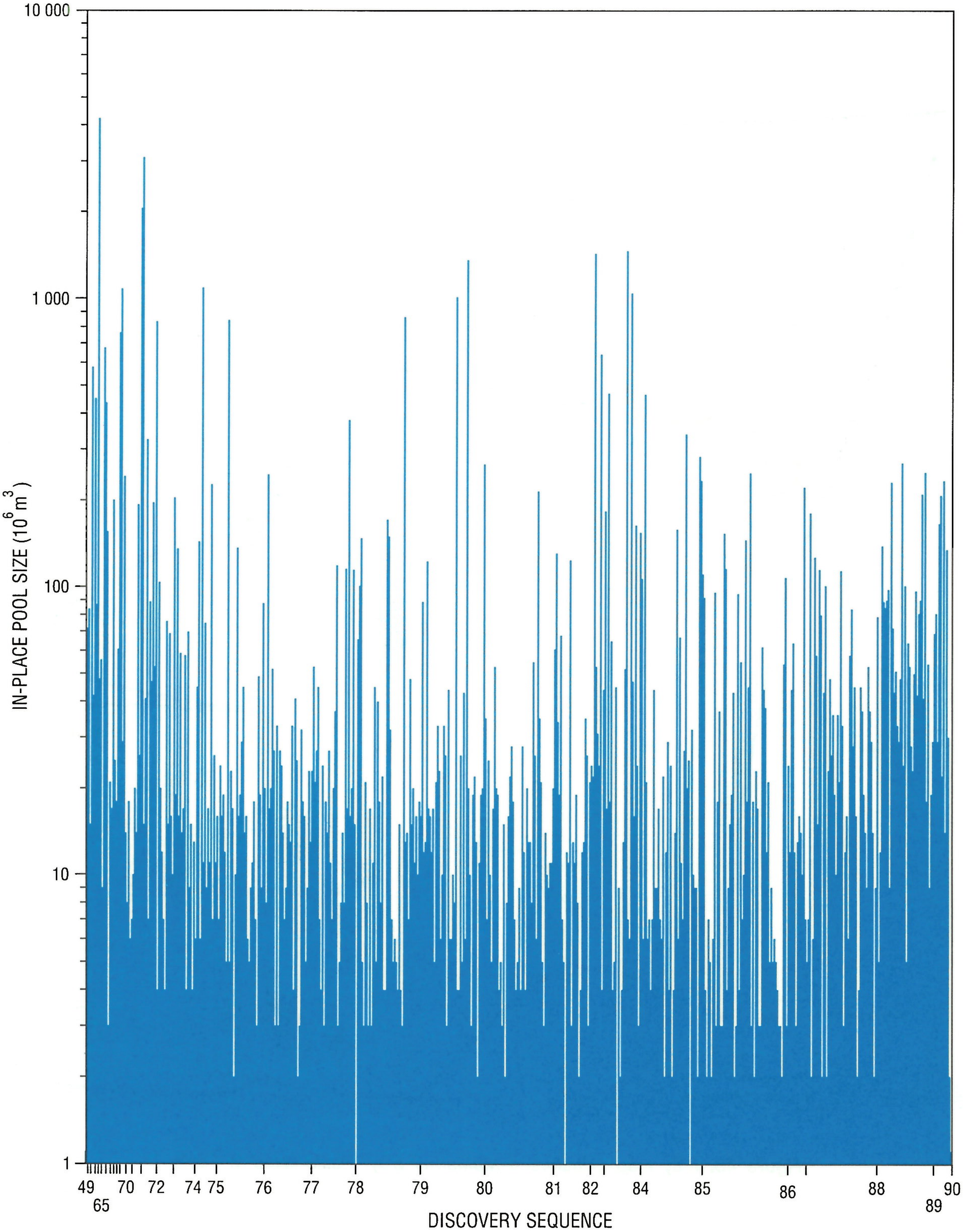


Figure 46. Discovery sequence: Athabasca-McMurray play.

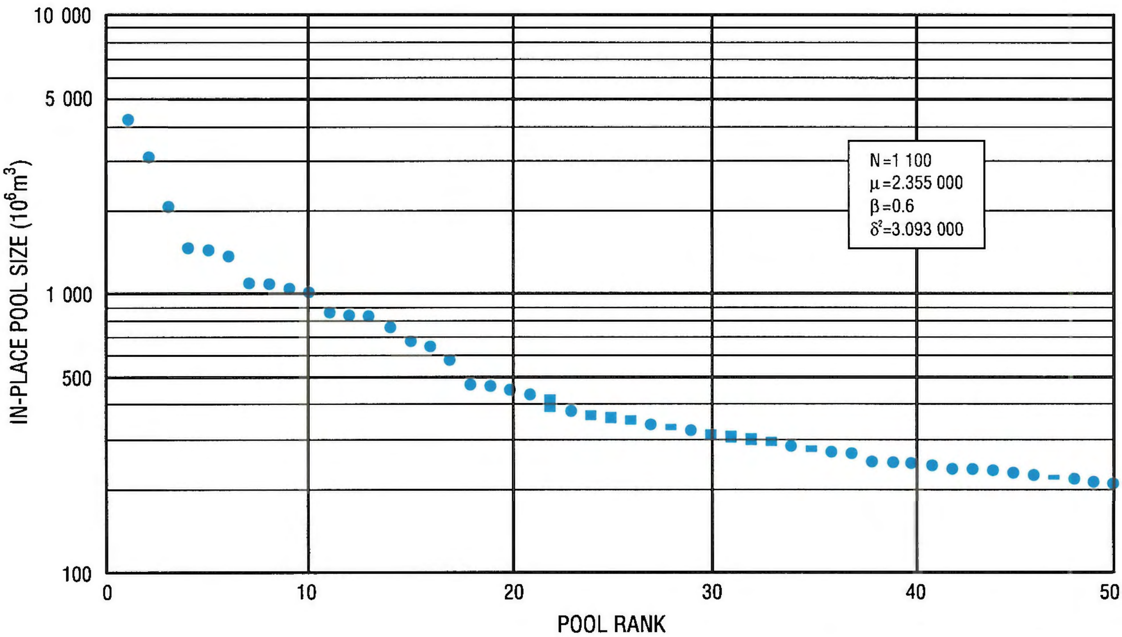


Figure 47. *Pool rank plot: Athabasca-McMurray play.*

Table 7

Summary of the Athabasca-McMurray play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Chard, McMurray B	NA	4 252	1957
2	Portage, McMurray A	NA	3 119	1972
3	Duncan, McMurray F	NA	2 072	1971
4	Hardy, McMurray E	NA	1 477	1984
5	Hardy, McMurray O	NA	1 445	1983
6	Liege, McMurray C	NA	1 370	1980
7	Newby, McMurray A	NA	1 098	1975
8	Nixon, Lower Mannville E	NA	1 087	1969
9	Thornbury, McMurray I	NA	1 053	1984
10	Liege, McMurray A	NA	1 020	1980
11	Hardy, McMurray A	NA	869	1979
12	Graham, McMurray B	NA	848	1976
13	Hylo, Lower Mannville A	NA	838	1972
14	Atmore, McMurray A	NA	766	1968
15	Tweedie, McMurray H	NA	680	1961
16	Thornbury, McMurray G	NA	646	1983
17	Tweedie, McMurray L	NA	582	1952
18	Newby, McMurray G	NA	472	1984
19	Thornbury, McMurray M	NA	468	1985
20	Tweedie, McMurray B	NA	453	1952
Initial in-place volume (discovered) (10^6 m^3)			45 450	
Initial in-place volume (potential) (10^6 m^3)			13 413	
Per cent of play resources undiscovered			23	
Total pools discovered			565	
Total pool population			1 100	

NA, nonassociated gas

Lloydminster

Colony to Lloydminster play

Play definition

This play includes all gas pools and prospects contained in the Lloydminster, Rex, General Petroleum, Sparky, Waseca, McLaren, and Colony members in the Lloydminster play area (Fig. 48).

Geology

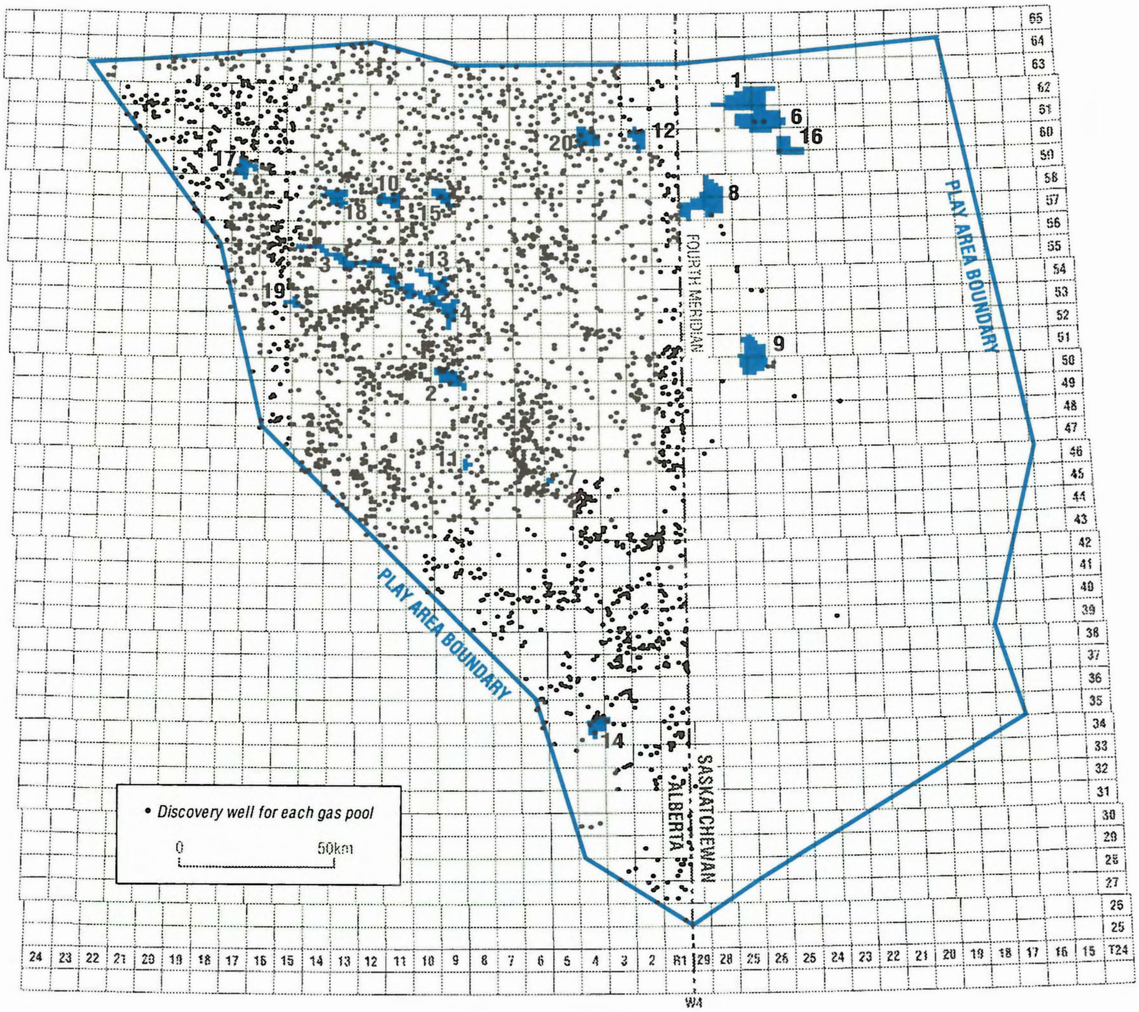
Both the facies and trapping mechanisms for this play have been well documented for several fields (Vigrass, 1977; Gross, 1980; Putnam, 1982; Zaitlin and Schultz, 1984) and these will not be repeated in detail here. The stratigraphic interval consists of at least seven transgressive-regressive shoreline successions, probably deposited as thin wave-dominated delta lobes, which have not been mapped in detail. Each of the regionally extensive shoreface sands is interrupted by a large number of linear valley-fills, cut during falls in relative sea level. In places, the orientation of these valleys is controlled by salt solution effects. The valley-fills vary from dominantly mudstone, which may function as seals to reservoirs in the shoreface sandstones, to dominantly sandstone, which function as reservoirs when surrounded by marine muds or fine grained, nonmarine to marginal marine deposits. Other traps occur where sandstones are draped over ridges or highs on the sub-Cretaceous unconformity. A few structures appear to result from drape over older sand-filled channels such as the Sparky Hayter field, which occurs in structural closure generated by compactional drape over a Dina channel. Many of the largest fields (e.g., Beacon Hill) occur in anticlines related to salt dissolution. Several traps are known to involve more than one mechanism; for example, a local drape structure in which hydrocarbons are trapped against a shale-filled channel.

Exploration history

The earliest discovery in this play was in 1947, but many of the largest fields were discovered in the late 1970s. There have been 3791 gas pools discovered in this play and the total discovered gas resource for the play is 212 535 x 10^6 m^3 (Figs. 48, 49; Table 8). The largest discovered gas pool in this play is the Beacon Hill Mannville Sand pool, which contains 3212 x 10^6 m^3 of gas-in-place.

Play potential

The estimated expected potential for this play is 87 008 x 10^6 m^3 of gas-in-place, based on a total pool population of 8860 (Table 8; Fig. 50). Based on this estimate, 29 per cent of the total gas resources for this play remains to be discovered. The largest undiscovered gas pool is predicted to have 255 x 10^6 m^3 of gas-in-place.



POOLS BY RANK

1 - BEACON HILL, MANNVILLE SAND
2 - MANNVILLE, UPPER MANNVILLE `F´
3 - HAIRY HILL, COLONY `W´
4 - BEAUVALLON, COLONY `K´
5 - DUVERNAY, COLONY `B´
6 - BEACON HILL SOUTH, MANNVILLE SAND
7 - WAINWRIGHT, SPARKY `A´
8 - PECK LAKE, COLONY SAND
9 - TANGLEFLAGS, COLONY SAND
10 - CACHE, CLEARWATER `B´
11 - VIKING - KINSELLA, UPPER MANNVILLE `EE´
12 - ANGLING, GRAND RAPIDS `B´
13 - BEAUVALLON, COLONY `L´
14 - MONITOR, UPPER MANNVILLE `A´
15 - ST. PAUL, UPPER MANNVILLE `A´
16 - MAKWA, MANNVILLE SAND
17 - BELLIS, UPPER MANNVILLE `B´
18 - STRY, UPPER MANNVILLE `A´
19 - WARWICK, UPPER MANNVILLE `K´
20 - CHARLOTTE LAKE, COLONY `A´

Figure 48. *Play map: Lloydminster–Colony to Lloydminister play. Pools listed in Table 8.*

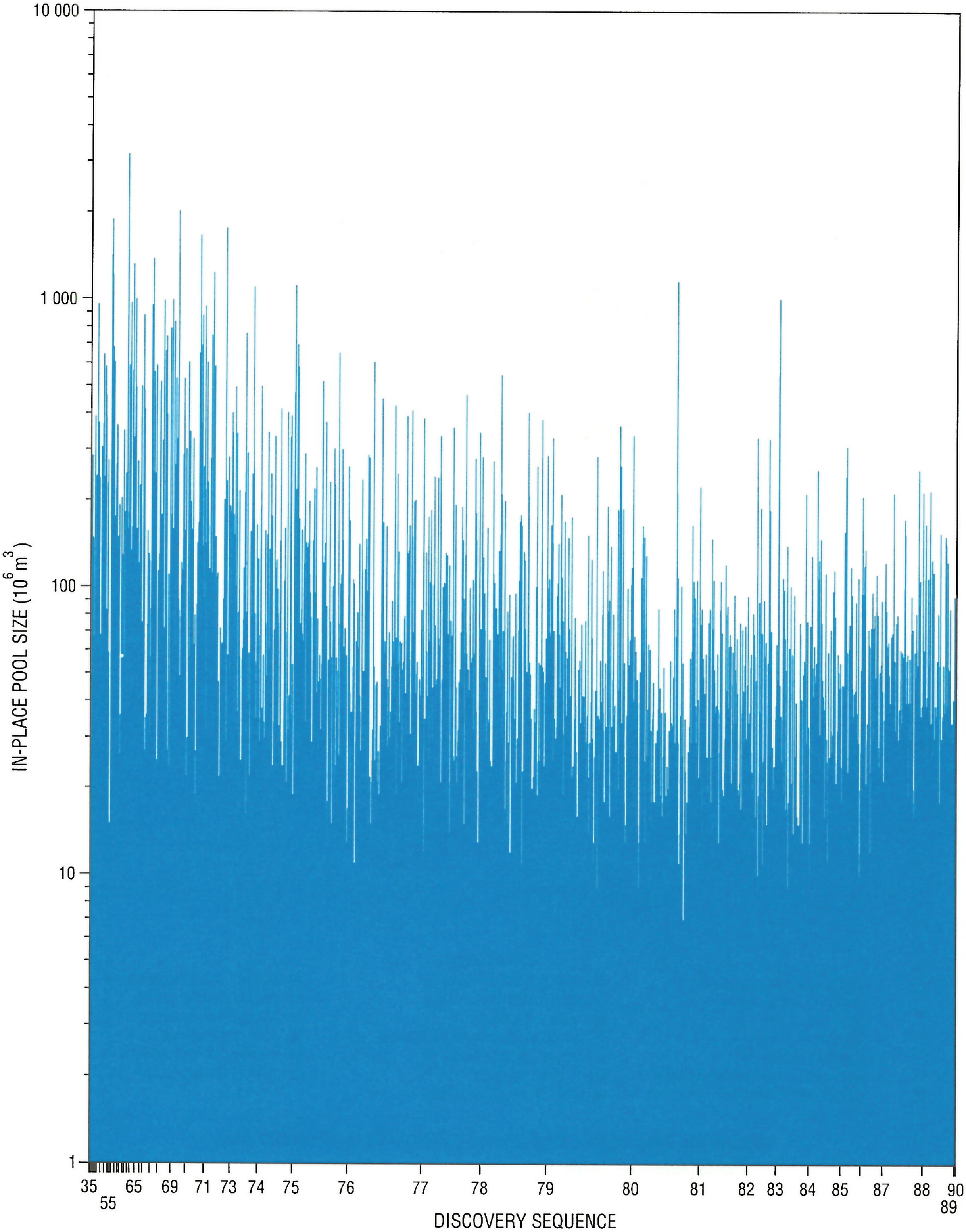


Figure 49. *Discovery sequence: Lloydminster–Colony to Lloydminster play.*

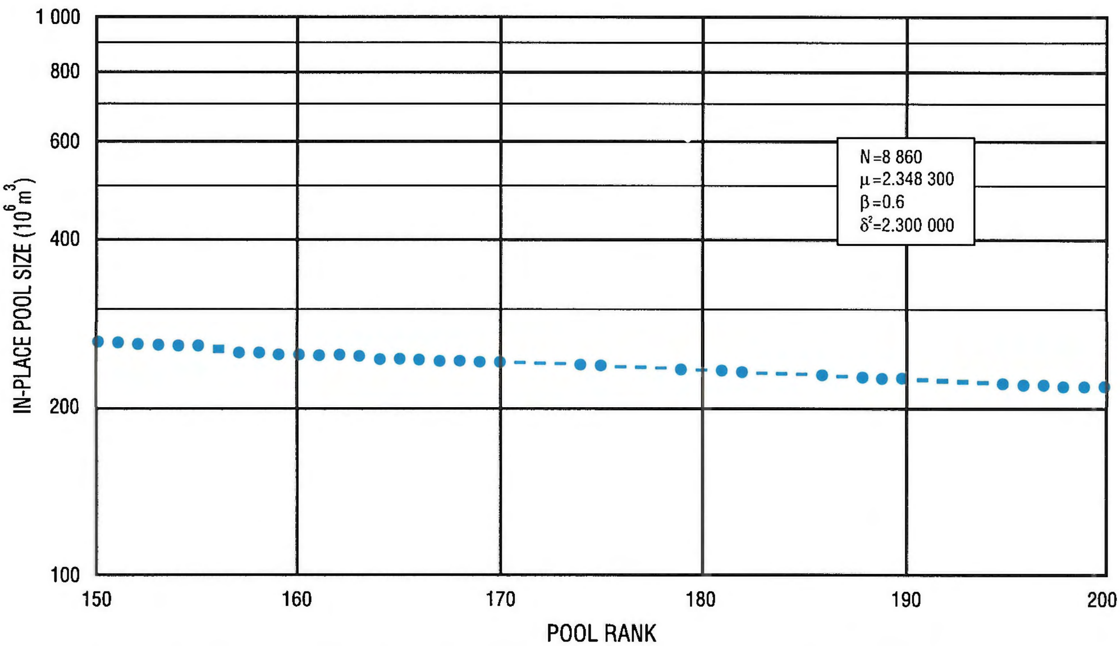


Figure 50. *Pool rank plot: Lloydminster–Colony to Lloydminster play.*

Table 8

Summary of the Lloydminster–Colony to Lloydminster play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Beacon Hill, Mannville Sand	NA	3 212	1963
2	Mannville, Upper Mannville F	NA	2 035	1971
3	Hairy Hill, Colony W	NA	1 900	1954
4	Beauvallon, Colony K	NA	1 784	1973
5	Duvernay, Colony B	NA	1 680	1972
6	Beacon Hill South, Mannville Sand	NA	1 483	1963
7	Wainwright, Sparky A	NA	1 426	1954
8	Peck Lake, Colony Sand	NA	1 393	1969
9	Tangleflags, Colony Sand	NA	1 332	1965
10	Cache, Clearwater B	NA	1 247	1973
11	Viking–Kinsella, Upper Mannville EE	NA	1 220	1955
12	Angling, Grand Rapids B	NA	1 172	1981
13	Beauvallon, Colony L	NA	1 126	1975
14	Monitor, Upper Mannville A	NA	1 115	1974
15	St. Paul, Upper Mannville A	NA	1 104	1947
16	Makwa, Mannville Sand	NA	1 022	1984
17	Bellis, Upper Mannville B	NA	1 007	1965
18	Stry, Upper Mannville A	NA	1 000	1970
19	Warwick, Upper Mannville K	NA	996	1970
20	Charlotte Lake, Colony A	NA	977	1964
Initial in-place volume (discovered) (10^6 m^3)			212 535	
Initial in-place volume (potential) (10^6 m^3)			87 008	
Per cent of play resources undiscovered			29	
Total pools discovered			3 791	
Total pool population			8 860	

NA, nonassociated gas

Cummings play

Play definition

This play includes all gas pools and prospects within the Cummings Formation in the Lloydminster play area (Fig. 51).

Geology

The Cummings Formation is the uppermost portion of the transgressive phase of the Mannville in the Lloydminster area, and corresponds to the Bluesky and Wabiskaw formations in other parts of the basin. The sediments are shoreface sandstones with associated nonmarine, marginal marine, and incised valley deposits. As in equivalent units, the shoreface successions are arranged in a southward backstepping pattern, but in this eastern, low subsidence area, more disconformities are present. As in the Wabiskaw, traps are formed stratigraphically and by salt solution effects.

Exploration history

The largest gas pool discovered in the Lloydminster–Cummings play is the Duvernay Wabiskaw G pool, with 343 x 10^6 m^3 of gas-in-place (Figs. 51, 52; Table 9). There have been 198 gas pools discovered in this play with a total in-place gas volume of 5216 x 10^6 m^3.

Play potential

The estimated expected potential for the Lloydminster–Cummings play is 2160 x 10^6 m^3 of gas-in-place, based on a total pool population of 540 (Table 9; Fig. 53). This estimate indicates that 29 per cent of the total gas resources for this play remains to be discovered. The largest undiscovered gas pool in this play is predicted to have 245 x 10^6 m^3 of gas-in-place.

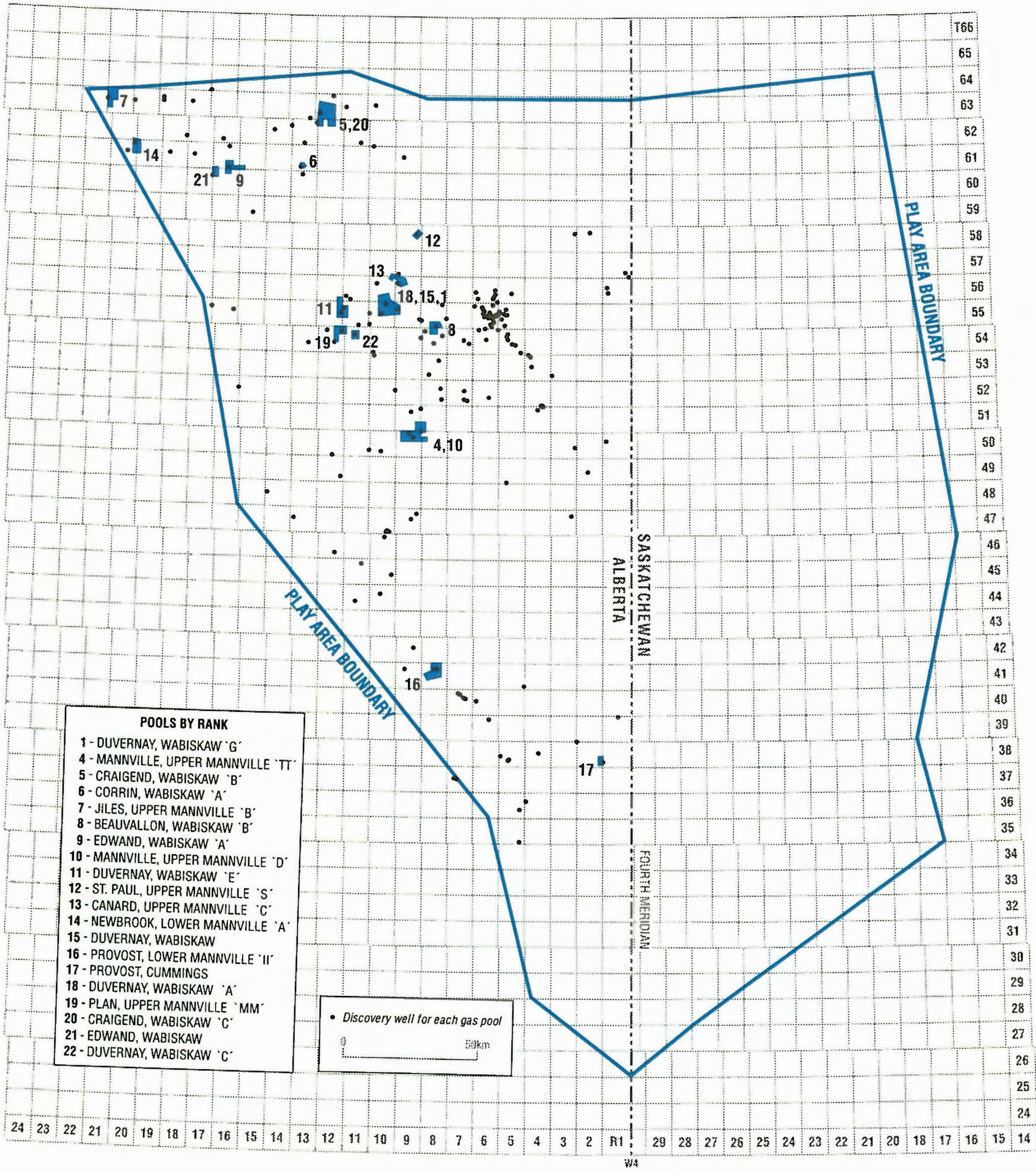


Figure 51. *Play map: Lloydminister–Cummings play. Pools listed in Table 9.*

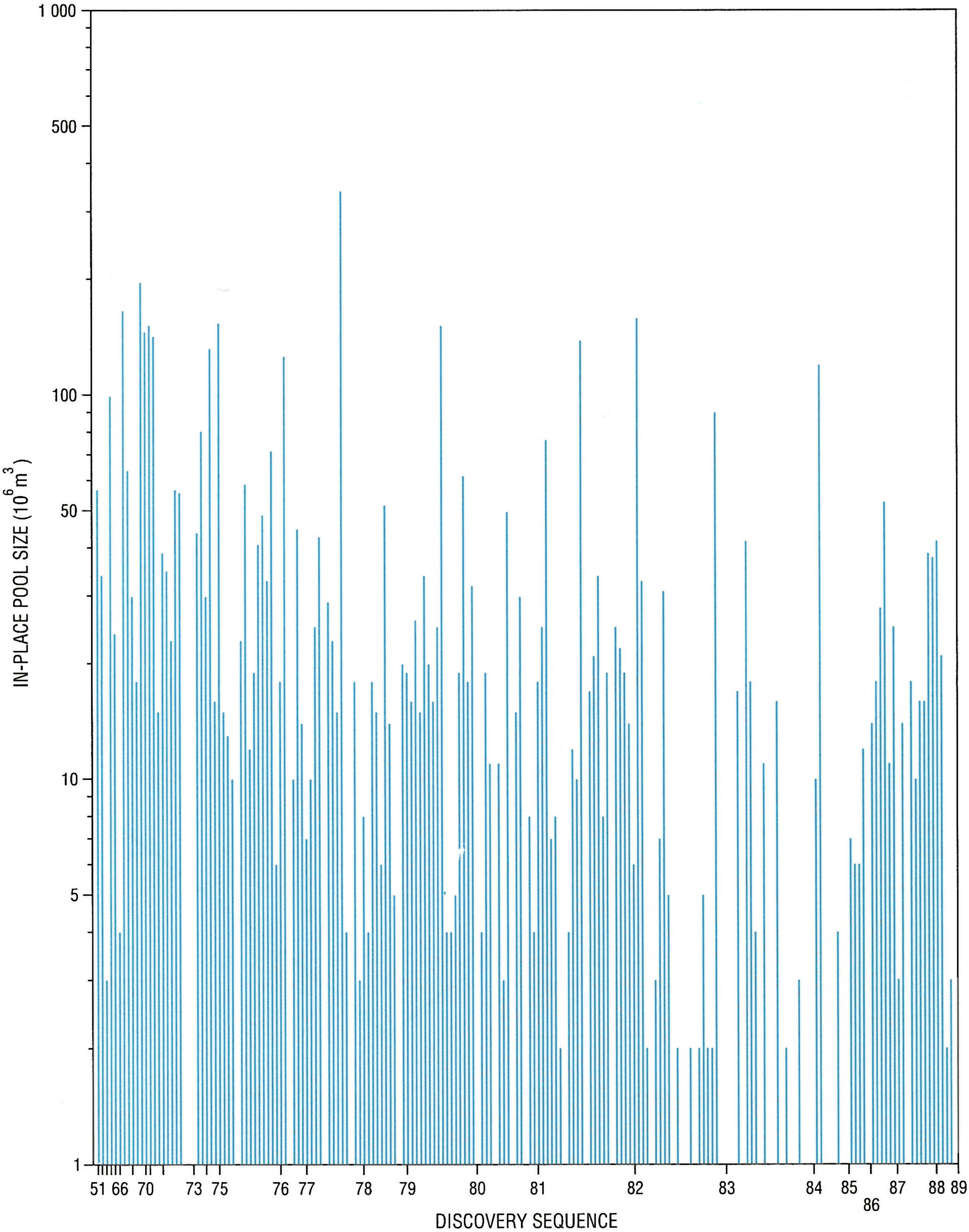


Figure 52. *Discovery sequence: Lloydminster–Cummings play.*

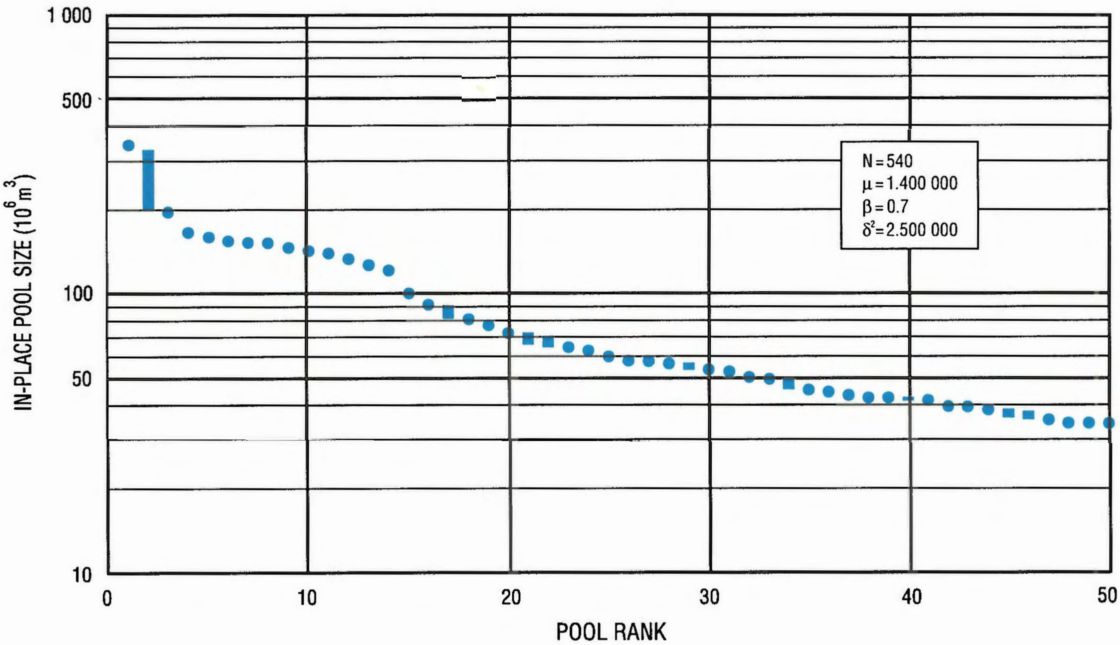


Figure 53. *Pool rank plot: Lloydminster–Cummings play.*

Table 9

Summary of the Lloydminster–Cummings play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Duvernay, Wabiskaw G	NA	343	1978
4	Mannville, Upper Mannville TT	NA	198	1970
5	Craigend, Wabiskaw B	NA	167	1969
6	Corrin, Wabiskaw A	NA	160	1983
7	Jiles, Upper Mannville B	NA	155	1975
8	Beauvallon, Wabiskaw B	NA	153	1980
9	Edwand, Wabiskaw A	NA	153	1971
10	Mannville, Upper Mannville D	NA	147	1970
11	Duvernay, Wabiskaw E	NA	143	1972
12	St. Paul, Upper Mannville S	NA	140	1982
13	Canard, Upper Mannville C	NA	133	1975
14	Newbrook, Lower Mannville A	NA	127	1977
15	Duvernay, Wabiskaw	NA	121	1985
16	Provost, Lower Mannville II	NA	100	1962
17	Provost, Cummings	NA	91	1983
18	Duvernay, Wabiskaw A	NA	81	1974
19	Plan, Upper Mannville MM	NA	77	1982
20	Craigend, Wabiskaw C	NA	72	1976
21	Edwand, Wabiskaw	NA	64	1969
22	Duvernay, Wabiskaw C	NA	62	1980
Initial in-place volume (discovered) (10^6 m^3)			5 216	
Initial in-place volume (potential) (10^6 m^3)			2 160	
Per cent of play resources undiscovered			29	
Total pools discovered			198	
Total pool population			540	

NA, nonassociated gas

Dina play

Play definition

This play includes all gas pools and prospects within the Dina Formation in the Lloydminster play area (Fig. 54).

Geology

The Dina Formation fills large valleys eroded into Palaeozoic rocks in east-central Alberta and west-central Saskatchewan. It is believed to be mainly fluvial (Gross, 1980) but has not been studied in detail. However, it is proximal to the brackish-water McMurray Formation in northeast Alberta, lending support to its probable fluvial origin. Many of the valley-fills show complex internal patterns, with sandstones as thick as 90 m laterally adjacent to mudstone-dominated facies. The major fields occur in areas of thick sandstone accumulation. Sandstone distribution is controlled by the sub-Mannville erosion surface. The trapping mechanism is varied: in some cases it is structural drape formed by salt solution, in other cases (e.g., Hayter field), lateral facies changes in the upper part of the valley-fill create a permeability barrier to fluid movement.

Exploration history

The largest gas pool discovered in the Dina play is the Craigend McMurray C pool, which has 1578 x 10^6 m^3 of gas-in-place and was discovered in 1953 (Figs. 54, 55; Table 10). There have been 230 gas pools discovered in this play and the total discovered in-place gas resource is 11 102 x 10^6 m^3.

Play potential

The estimated expected potential for the Dina play is 13 283 x 10^6 m^3 of gas-in-place, based on a total pool population of 800 (Table 10; Fig. 56). Based on this estimate 54 per cent of the total resources for this play remains to be discovered. The largest undiscovered pool in this play is estimated to contain 840 x 10^6 m^3 of gas-in-place.

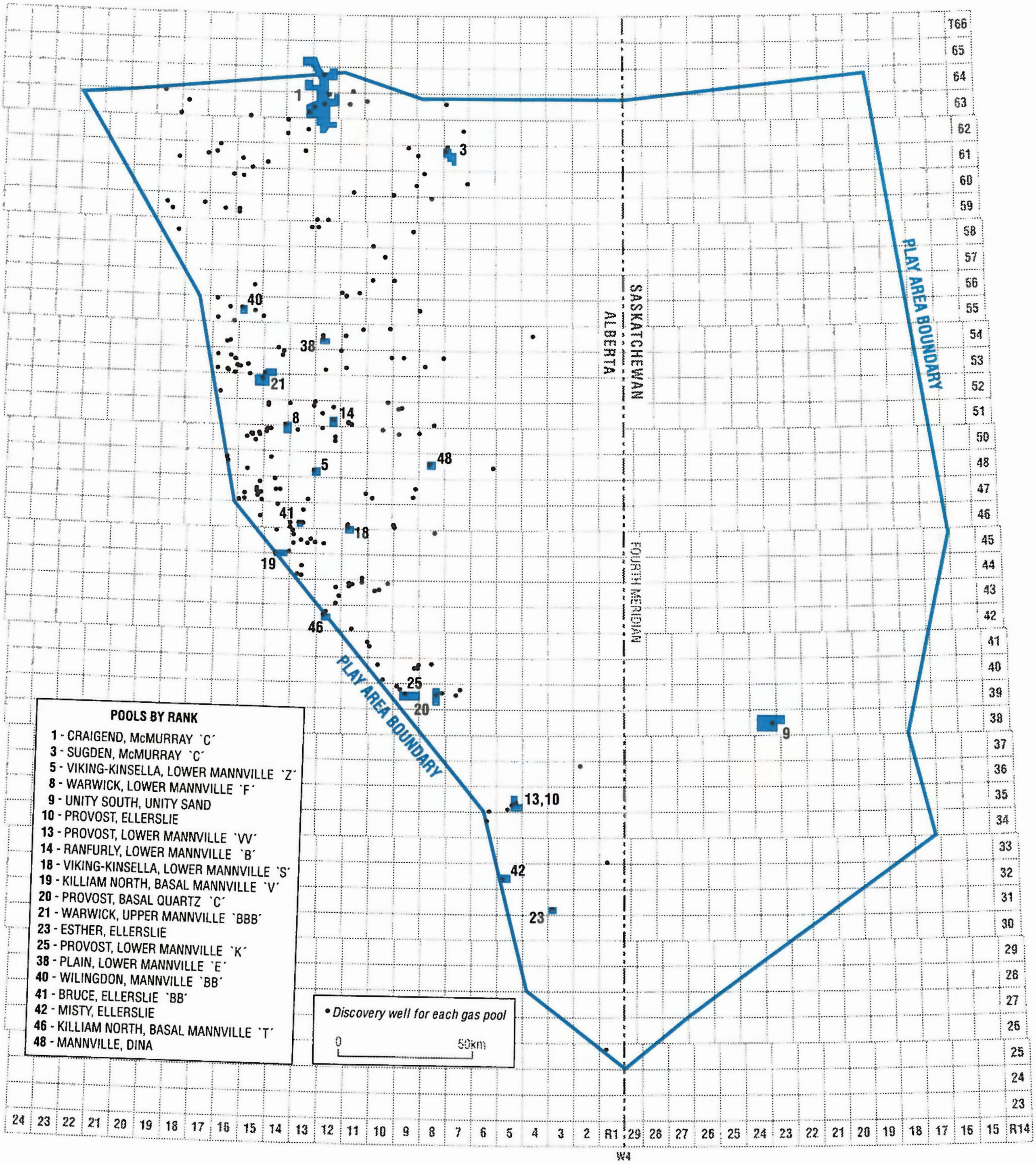


Figure 54. Play map: Lloydminister–Dina play. Pools listed in Table 10.

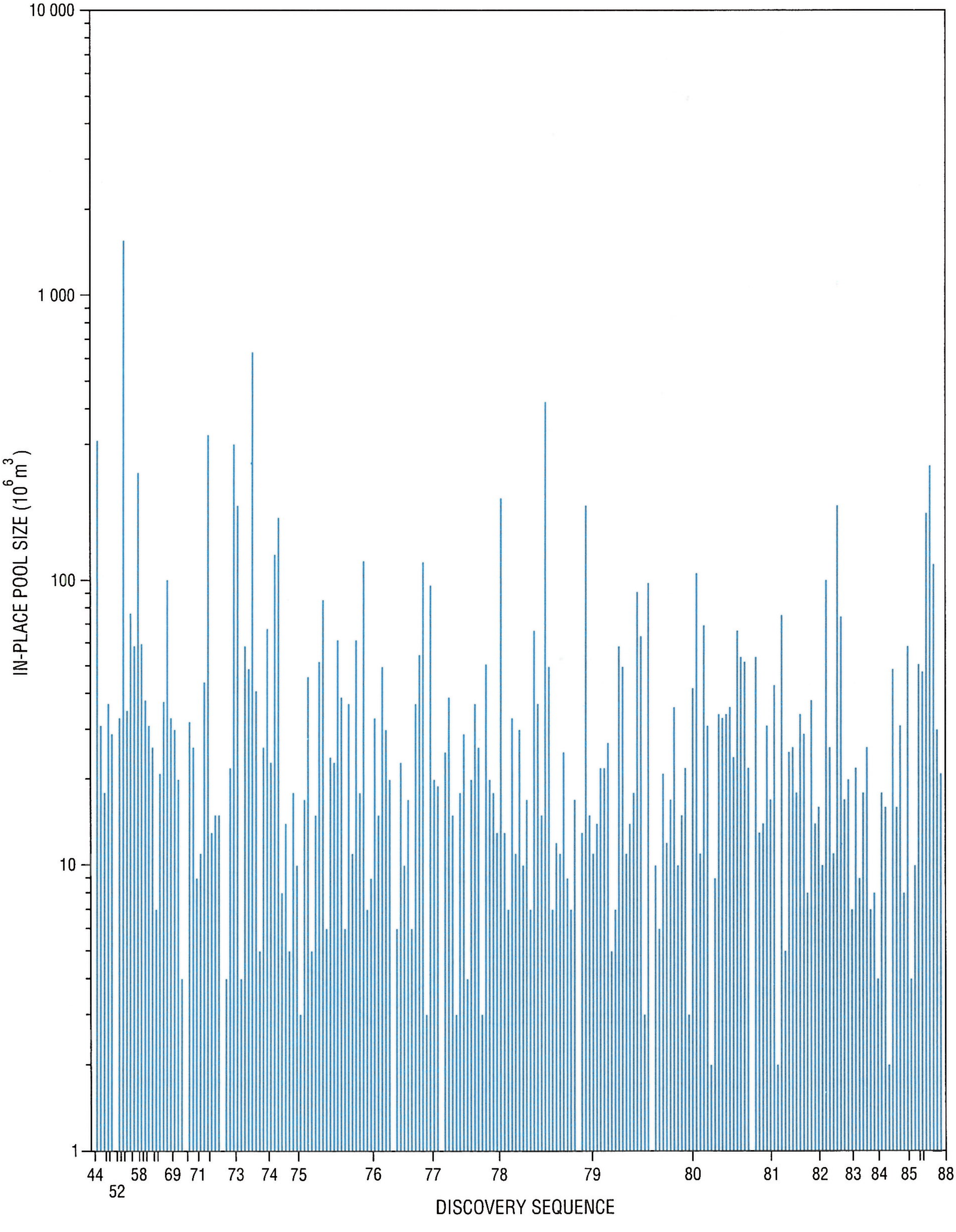


***Figure 55.** Discovery sequence: Lloydminster–Dina play.*

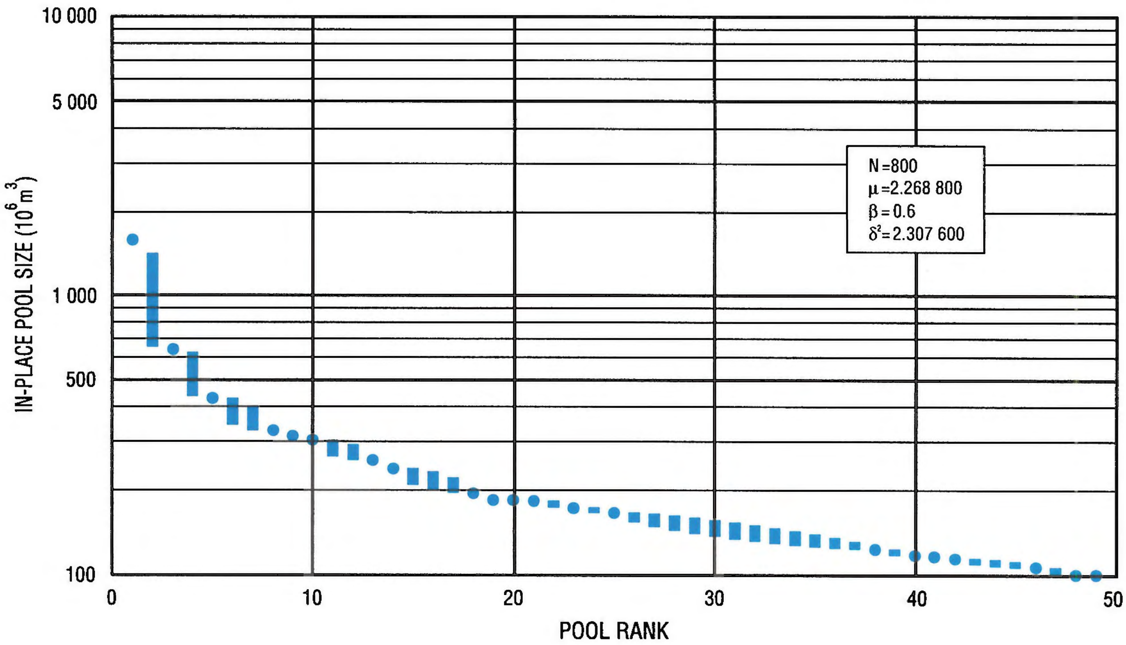


Figure 56. *Pool rank plot: Lloydminster–Dina play.*

Table 10

Summary of the Lloydminster–Dina play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Craigend, McMurray C	NA	1 578	1953
3	Sugden, McMurray C	NA	640	1974
5	Viking–Kinsella, Lower Mannville Z	NA	429	1979
8	Warwick, Lower Mannville F	NA	327	1972
9	Unity South, Unity Sand	NA	312	1944
10	Provost, Ellerslie	NA	303	1973
13	Provost, Lower Mannville VV	NA	256	1988
14	Ranfurly, Lower Mannville B	NA	240	1958
18	Viking–Kinsella, Lower Mannville S	NA	196	1978
19	Killiam North, Basal Mannville V	NA	185	1979
20	Provost, Basal quartz C	AG, SG	185	1983
21	Warwick, Upper Mannville BBB	NA	184	1973
23	Esther, Ellerslie	NA	174	1988
25	Provost, Lower Mannville K	NA	167	1975
38	Plain, Lower Mannville E	NA	124	1975
40	Willingdon, Mannville BB	NA	118	1976
41	Bruce, Ellerslie BB	NA	117	1977
42	Misty, Ellerslie	NA	115	1988
46	Killiam North, Basal Mannville T	NA	107	1981
48	Mannville, Dina	NA	101	1983
Initial in-place volume (discovered) (10^6 m^3)			11 102	
Initial in-place volume (potential) (10^6 m^3)			13 283	
Per cent of play resources undiscovered			54	
Total pools discovered			230	
Total pool population			800	

NA, nonassociated gas; AG, associated gas; SG, sour gas

Central Alberta

Glauconite/Upper Mannville play

Play definition

This play includes all gas pools and prospects in the Glauconite Formation and the Upper Mannville Group (Fig. 57). Because of the complex stratigraphy of these units, stratigraphic division of the pool database was difficult; consequently these units were grouped into one play. The pools in the Glauconite far outnumber those in the Upper Mannville and they also have larger in-place gas volumes.

Geology

The Glauconite Formation is one of the most important reservoir units in the Mannville and has been well studied (Chiang, 1984; Strobl, 1986; Rosenthal, 1989; Karvonen and Pemberton, 1989). The unit prograded to the northwest, but numerous fluctuations in relative sea-level occurred, each generating incision of rivers and deposition of isolated lowstand shoreface sandstones (e.g., Hoadley and Pembina fields). The incised valleys were commonly backfilled during the subsequent transgressions by estuarine sediments (Wood and Hopkins, 1989; Karvonen and Pemberton, 1989).

Stratigraphic trapping is very effective in the Glauconite because of the large number of lowstand sandstones and incised valleys (e.g., Cessford H pool), which have been a major exploration target for many years. The Hoadley field contains gas downdip to the southwest and water updip to the northeast, apparently in the same reservoir unit (Chiang, 1984). A "Deep-Basin" trapping mechanism (discussed for Upper Mannville, northwest Alberta/northeast British Columbia) has therefore been invoked.

The Upper Mannville in this area is dominantly fine grained. The thicker (up to 20 m) fluvial sandstones are nonmarine valley-fills, and probably resulted from the same fluctuations in relative sea level as those that affected Falher shorelines to the north (basinward). The thinner fluvial sandstones (up to about 8 m) may be channels contemporaneous with the adjacent overbank deposits, but the distinction is not certain at present. Reservoirs occur in the fluvial sandstones, trapped by a combination of lateral gradation into shales, and in some cases, structural drape over highs on the unconformity (e.g., Leo Upper Mannville F pool).

Exploration history

The largest discovered gas pool in this play is the Westerose South Glauconite A pool, which has 23 810 x 10^6 m^3 of gas-in-place and was discovered in 1977. There have been 2335 pools discovered in this play with a total in-place gas volume of 315 572 x 10^6 m^3 (Figs. 57, 58; Table 11).

Play potential

The estimated expected potential for this play is 91 411 x 10^6 m^3 of gas-in-place, based on a total pool population of 4380 (Table 11; Fig. 59). This estimate indicates that 22 per cent of the total gas resources for this play remains to be discovered. The largest undiscovered gas pool is predicted to have 1127 x 10^6 m^3 of gas-in-place.

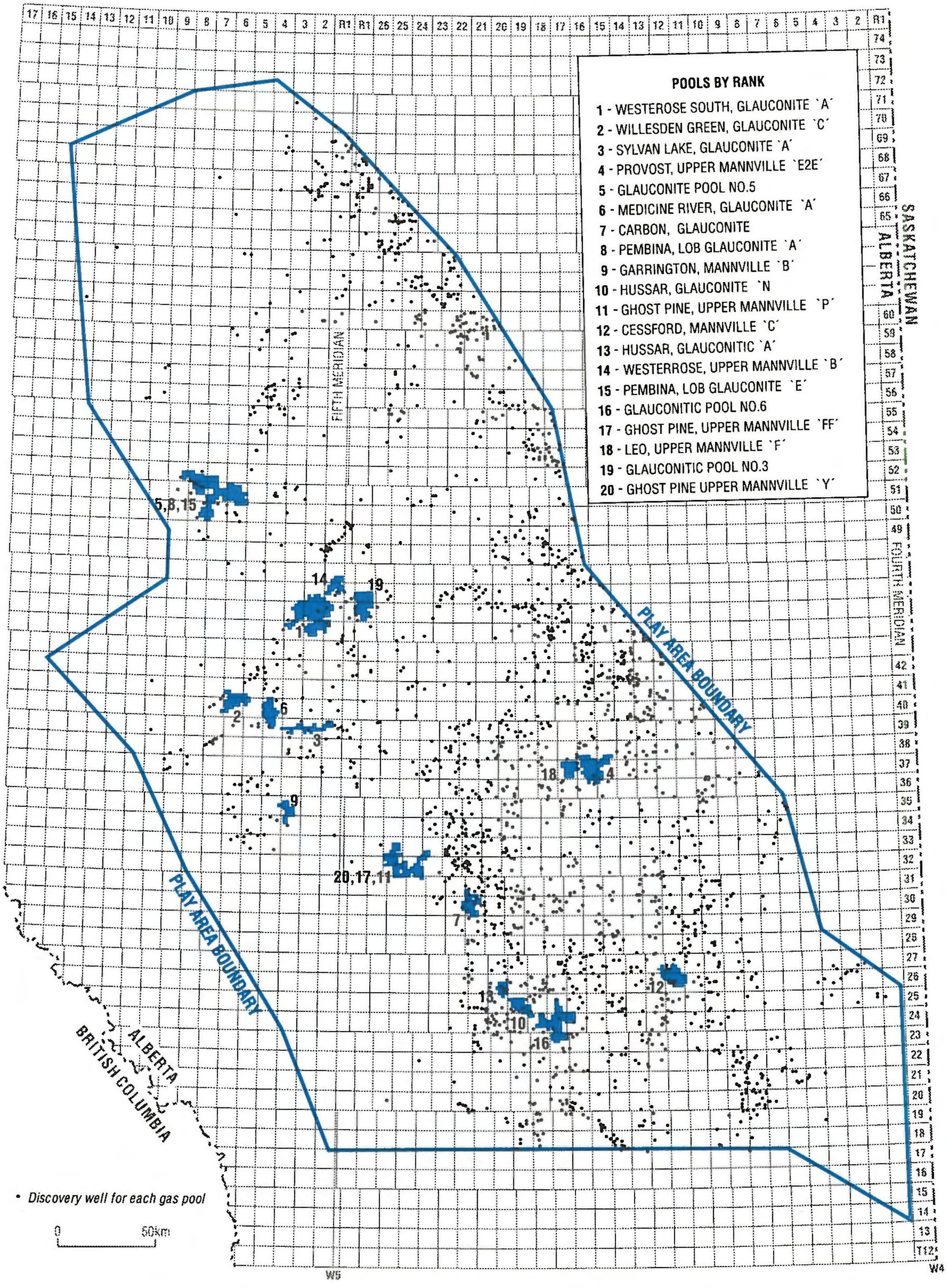


Figure 57. *Play map: central Alberta–Glauconite/Upper Mannville play. Pools listed in Table 11.*

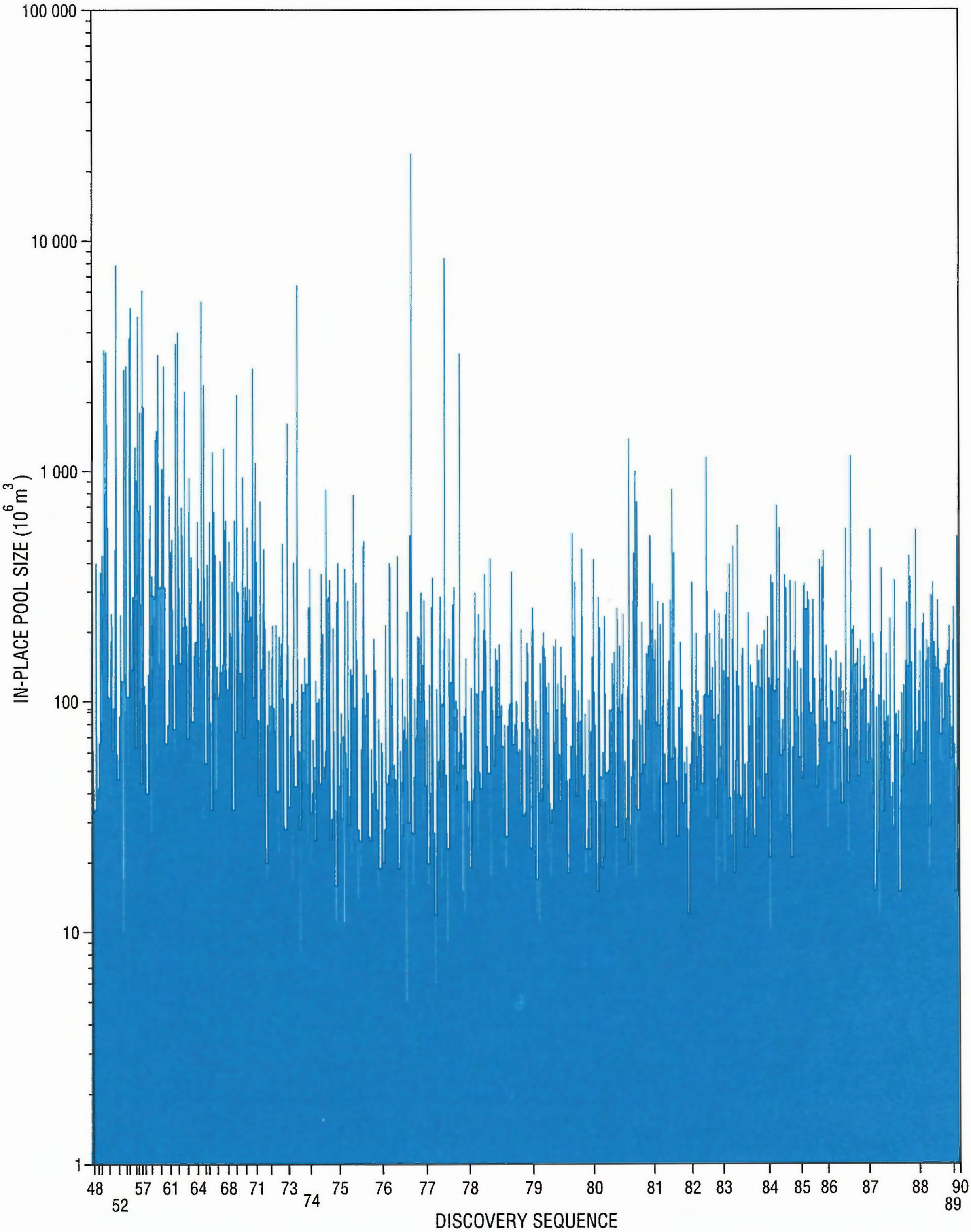


***Figure 58.** Discovery sequence: central Alberta–Glauconite/Upper Mannville play.*

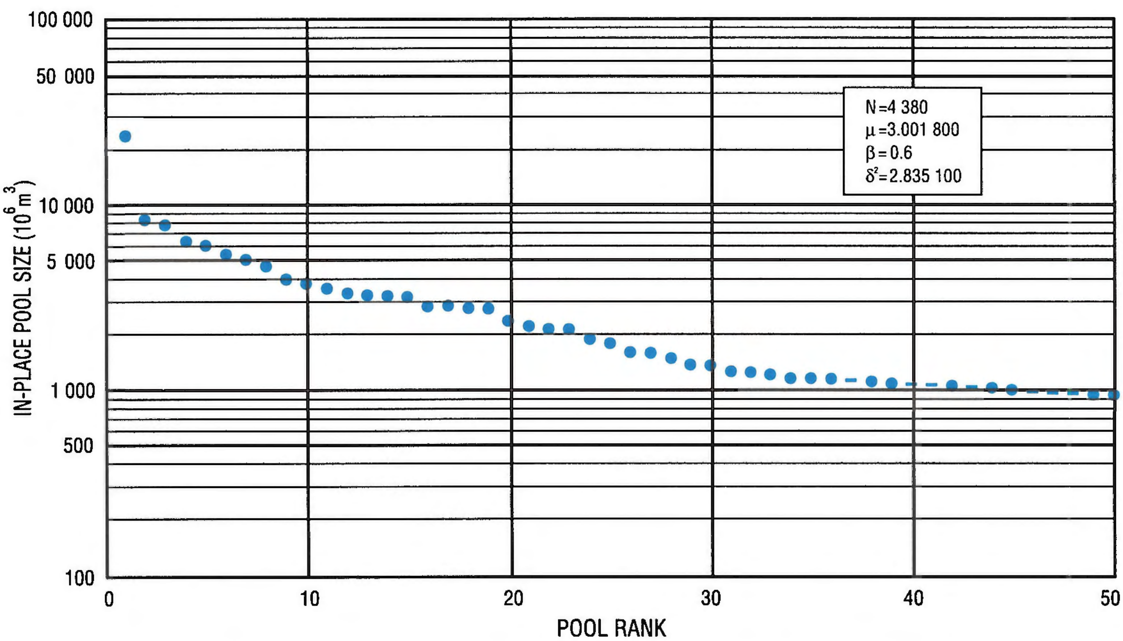


Figure 59. *Pool rank plot: central Alberta–Glauconite/Upper Mannville play.*

Table 11

Summary of the central Alberta–Glauconite/Upper Mannville play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Westerose South, Glauconite A	NA	23 810	1977
2	Willesden Green, Glauconite C	NA	8 413	1978
3	Sylvan Lake, Glauconite A	NA	7 843	1952
4	Provost, Upper Mannville E2E	NA	6 415	1974
5	Glauconite Pool No. 5	NA	6 080	1958
6	Medicine River, Glauconite A	AG, SG	5 442	1965
7	Carbon, Glauconite	NA	5 101	1955
8	Pembina, Lob Glauconite A	NA	4 692	1957
9	Garrington, Mannville B	NA	4 000	1963
10	Husar, Glauconite N	NA	3 766	1955
11	Ghost Pine, Upper Mannville P	NA	3 561	1962
12	Cessford, Mannville C	AG, SG	3 357	1951
13	Hussar, Glauconitic A	AG, SG	3 290	1951
14	Westerose, Upper Mannville B	NA	3 236	1978
15	Pembina, Lob Glauconite E	NA	3 200	1960
16	Glauconitic Pool No. 6	NA	2 861	1954
17	Ghost Pine, Upper Mannville FF	NA	2 859	1961
18	Leo, Upper Mannville F	AG, SG	2 797	1971
19	Glauconitic Pool No. 3	NA	2 755	1953
20	Ghost Pine, Upper Mannville Y	NA	2 370	1966
Initial in-place volume (discovered) (10^6 m^3)			315 572	
Initial in-place volume (potential) (10^6 m^3)			91 411	
Per cent of play resources undiscovered			22	
Total pools discovered			2 335	
Total pool population			4 380	

NA, nonassociated gas; AG, associated gas; SG, sour gas

Ostracod play

Play definition

This play includes all gas pools and prospects in the Ostracod Member in central Alberta (Fig. 60). In general, Ostracod sandstones are recognizable in this area and the database is sufficiently reliable for the pools to be classified correctly.

Geology

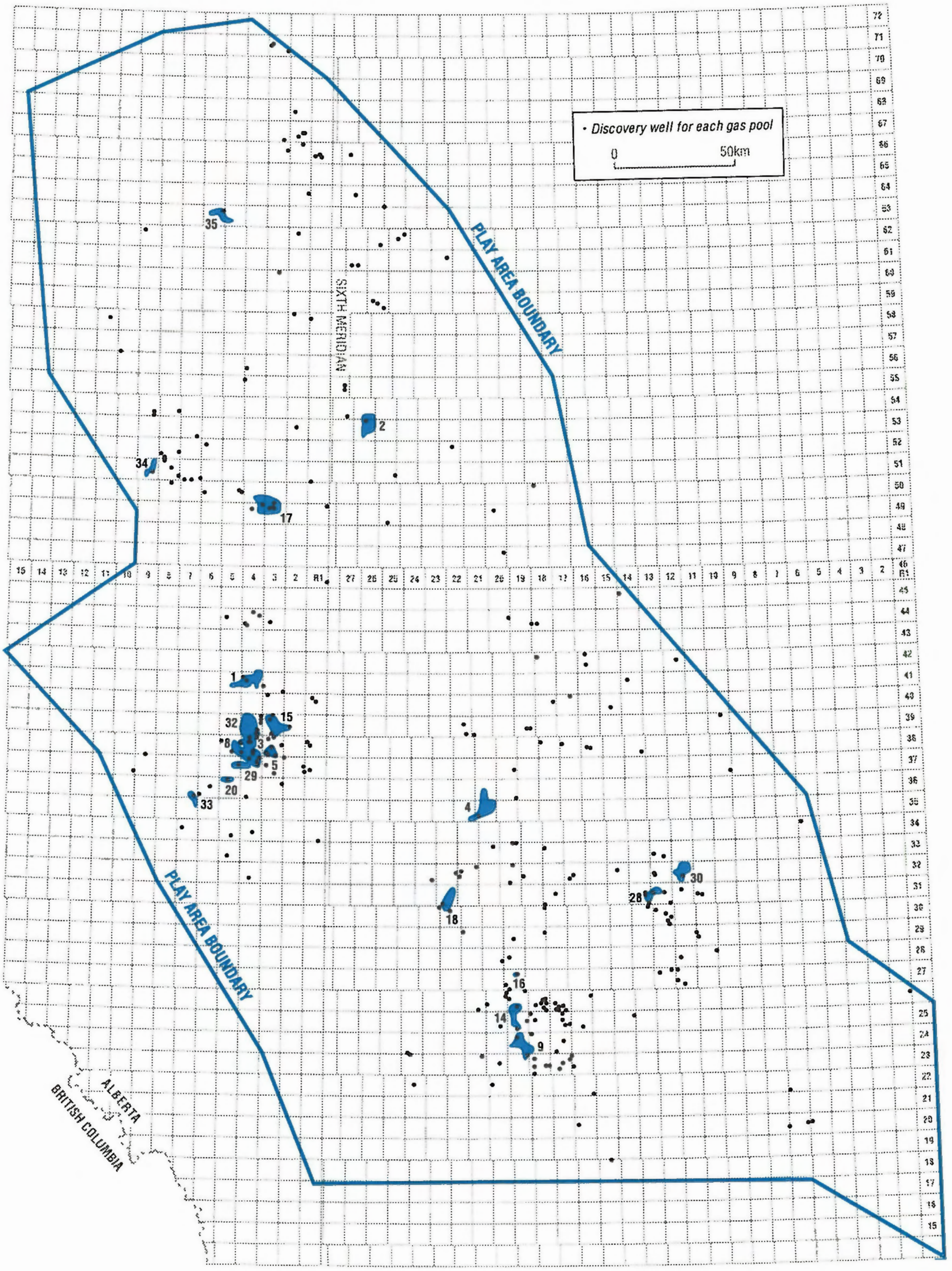
The Ostracod Member is a thin, diachronous unit of calcareous mudstone with interbedded limestone, which was deposited in a series of marine bays, brackish-water lagoons, and freshwater lakes. This unit or facies is found lying behind the shoreface sandstones of the Bluesky Formation (in the north) and the Gluaconite Formation (in the south). The reservoirs are a series of thin, lowstand, shoreface sandstones that could be correlative to some Glauconite lowstand sandstones or incised valley-fills. The trapping mechanisms are dominated by facies changes, with the reservoirs essentially encased by calcareous mudstones (e.g., St. Alberta–Big Lake Ostracod A pool). A few traps involve structural drape over Palaeozoic ridges on the unconformity.

Exploration history

The largest discovered gas pool in the Central Alberta-Ostracod play is the Gilby Basal Mannville H pool, which has 5229 x 10^6 m^3 of gas-in-place. There have been 297 gas pools discovered in this play, with a total of 38 084 x 10^6 m^3 of gas-in-place (Figs. 60, 61; Table 12).

Play potential

The estimated expected potential for this play is 16 677 x 10^6 m^3 of gas-in-place, based on a total pool population of 500 (Table 12; Fig. 62). This estimate indicates that 30 per cent of the total gas resources for this play remains to be discovered. The largest undiscovered gas pool is predicted to have 1346 x 10^6 m^3 of gas-in-place.



POOLS BY RANK

1 - GILBY, BASAL MANNVILLE 'H'
2 - ST. ALBERT-BIG LAKE, OSTRACOD 'A'
3 - MEDICINE RIVER, OSTRACOD 'C'
4 - RICH, LOWER MANNVILLE 'A'
5 - SYLVAN LAKE, L. MANNVILLE 'A'
8 - SYLVAN LAKE, OSTRACOD 'K'
9 - HUSSAR, OSTRACOD 'F'
14 - HUSSAR, OSTRACOD 'R'
15 - MEDICINE RIVER, OSTRACOD 'A'
16 - WAYNE-ROSEDALE, OSTRACOD 'A'
17 - PEMBINA, OSTRACOD 'E'
18 - TWINING, LOWER MANNVILLE 'B'
20 - GARRINGTON, L. MANNVILLE 'ZZ'
28 - RICHDALE, LOWER MANNVILLE 'T'
29 - SYLVAN LAKE, OSTRACOD 'N'
30 - GARDEN PLAINS, L. MANNVILLE 'D'
32 - MEDICINE RIVER, OSTRACOD 'B'
33 - CAROLINE, OSTRACOD 'A'
34 - BIGORAY, OSTRACOD 'D'
35 - DORIS, LOWER MANNVILLE 'A'

Figure 60. *Play map: central Alberta–Ostracod play. Pools listed in Table 12.*

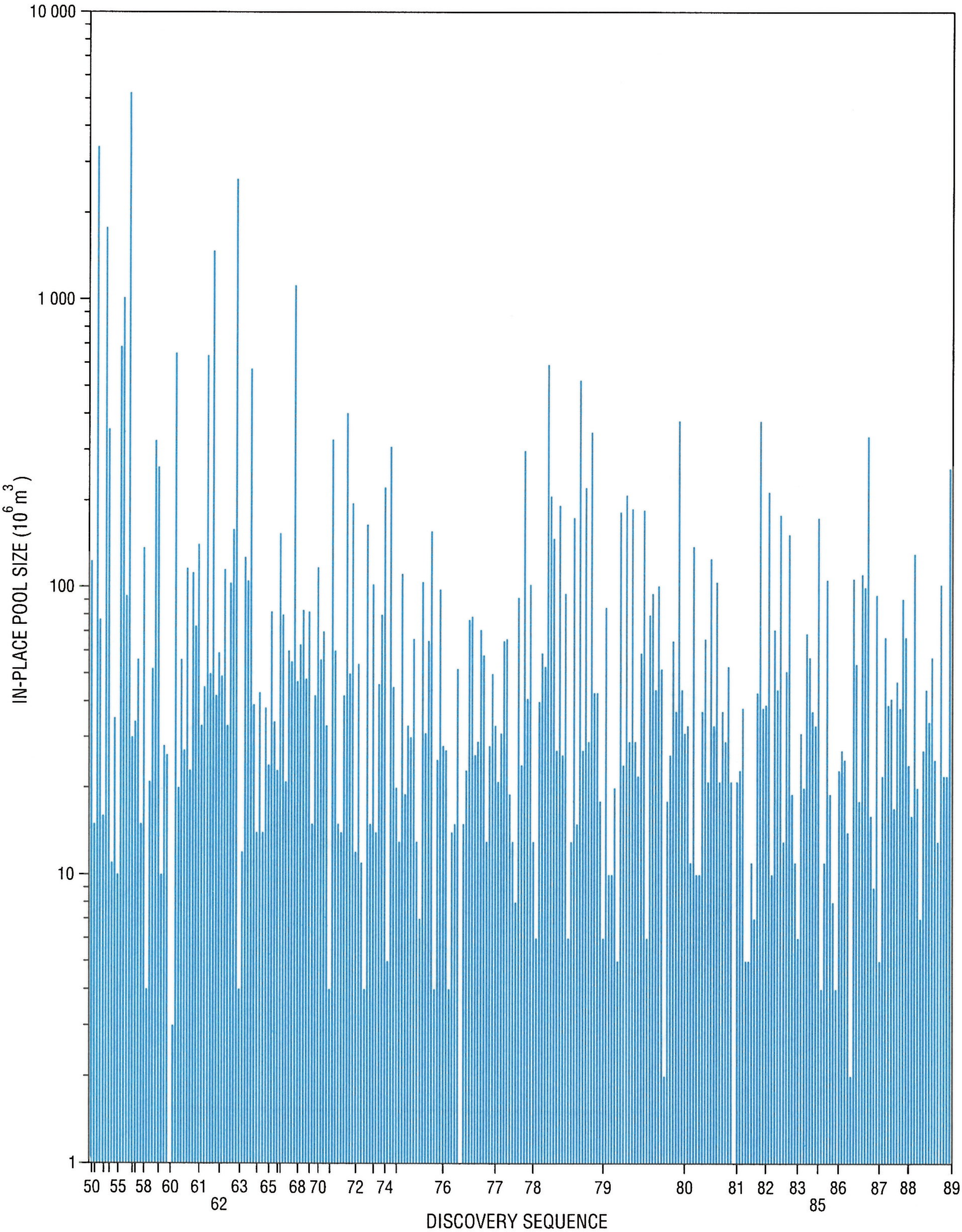


Figure 61. *Discovery sequence: central Alberta–Ostracod play.*

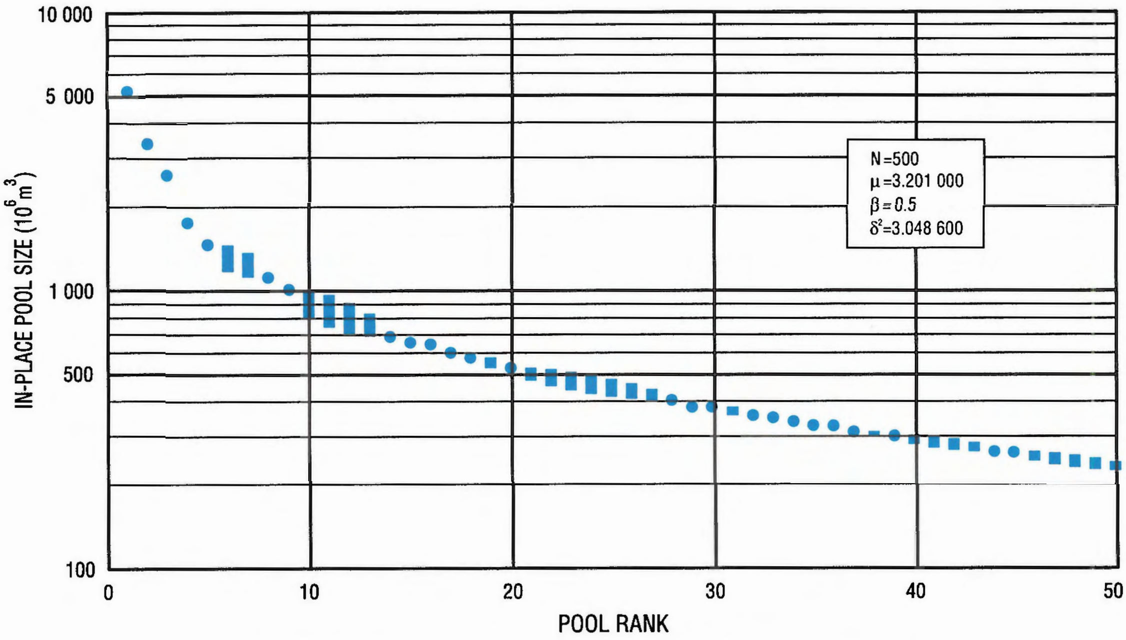


***Figure 62.** Pool rank plot: central Alberta-Ostracod play.*

Table 12

Summary of the central Alberta-Ostracod play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Gilby, Basal Mannville H	NA	5 229	1956
2	St. Albert-Big Lake, Ostracod A	NA	3 393	1952
3	Medicine River, Ostracod C	AG, SG	2 623	1963
4	Rich, Lower Mannville A	NA	1 777	1953
5	Sylvan Lake, Lower Mannville A	NA	1 474	1962
8	Sylvan Lake, Ostracod K	NA	1 120	1968
9	Hussar, Ostracod F	NA	1 013	1956
14	Hussar, Ostracod R	NA	685	1956
15	Medicine River, Ostracod A	AG, SG	652	1961
16	Wayne-Rosedale, Ostracod A	NA	639	1962
17	Pembina, Ostracod E	AG, SG	596	1979
18	Twining, Lower Mannville B	NA	575	1964
20	Garrington, Lower Mannville ZZ	NA	526	1979
28	Richdale, Lower Mannville T	NA	403	1972
29	Sylvan Lake, Ostracod N	NA	380	1980
30	Garden Plains, Lower Mannville D	NA	379	1982
32	Medicine River, Ostracod B	AG, SG	354	1953
33	Caroline, Ostracod A	NA	347	1979
34	Bigoray, Ostracod D	NA	336	1987
35	Doris, Lower Mannville A	NA	326	1972
Initial in-place volume (discovered) (10^6 m^3)			38 084	
Initial in-place volume (potential) (10^6 m^3)			16 677	
Per cent of play resources undiscovered			30	
Total pools discovered			297	
Total pool population			500	

NA, nonassociated gas; AG, associated gas; SG, sour gas

Lower Mannville–Basal Quartz/Ellerslie play

Play definition

This play includes all gas pools and prospects contained in the Lower Mannville Group, which includes the Basal Quartz and Ellerslie formations, of the central Alberta play area (Fig. 63).

Geology

The isopach map of the transgressive systems tract (Fig. 13) shows that the most critical factor controlling Lower Mannville reservoirs is the topography on the basal unconformity. The valleys in the area are cut on westward-dipping Mississippian to Jurassic sediments, and are filled by a variety of lithofacies. The Basal Quartz is a quartz- and chert-dominated sandstone with some conglomerate, which fills the basal parts of the valleys. Similar to the Cadomin, it is believed to be unconformity-bounded, and possibly much older than the remainder of the unit. The finer-grained Ellerslie Formation also fills the valleys, but overtops many of the uplands. During Ellerslie deposition, some of the valleys were cut off from a supply of clastics, with the result that marine (Farshori and Hopkins, 1989) and lacustrine sediments filled portions of the valleys. Some cores contain micritic limestones up to 2 m thick within the Ellerslie Formation. A series of coarse grained sandstone bodies within the unit may be the fill of smaller incised valleys. Its top is gradational into the marginal marine to lagoonal sediments of the Ostracod Member.

The distribution of pools in the Lower Mannville is almost completely controlled by the valleys cut on the sub-Mannville unconformity. Three types of traps have been discovered. Perhaps the most common is lateral onlap and pinchout of the Basal Quartz against impermeable rocks of the valley wall (e.g., Gilby basal Mannville A pool), particularly in narrow valleys or near their upstream terminations. In wider depositional areas, especially in the Ellerslie Formation, lateral facies changes from channel sandstones to overbank shales also trap gas in some pools (e.g., Caroline basal Mannville pools). Finally, structural drape over ridges of Palaeozoic strata has created closure for some pools (e.g., Ellerslie pool #1).

Exploration history

There have been 2451 gas pools discovered in the Lower Mannville Group in the central Alberta play-area. The total discovered gas-in-place for the play is 257 755 x 10^6 m^3. Many of the pools in this play were discovered in the 1950s and 1960s (Figs. 63, 64; Table 13). The largest discovered gas pool is the Gilby Basal Mannville A pool, which was discovered in 1956 and has 8028 x 10^6 m^3 of gas-in-place. Future discoveries may be smaller, and may involve internal unconformities within the Lower Mannville.

Play potential

The estimated expected play potential is 67 399 x 10^6 m^3 of gas-in-place, based on a total pool population of 4400 (Table 13; Fig. 65). This estimate indicates that 21 per cent of the total play resources remains to be discovered. The largest undiscovered pool is predicted to have 1112 x 10^6 m^3 of gas-in-place.

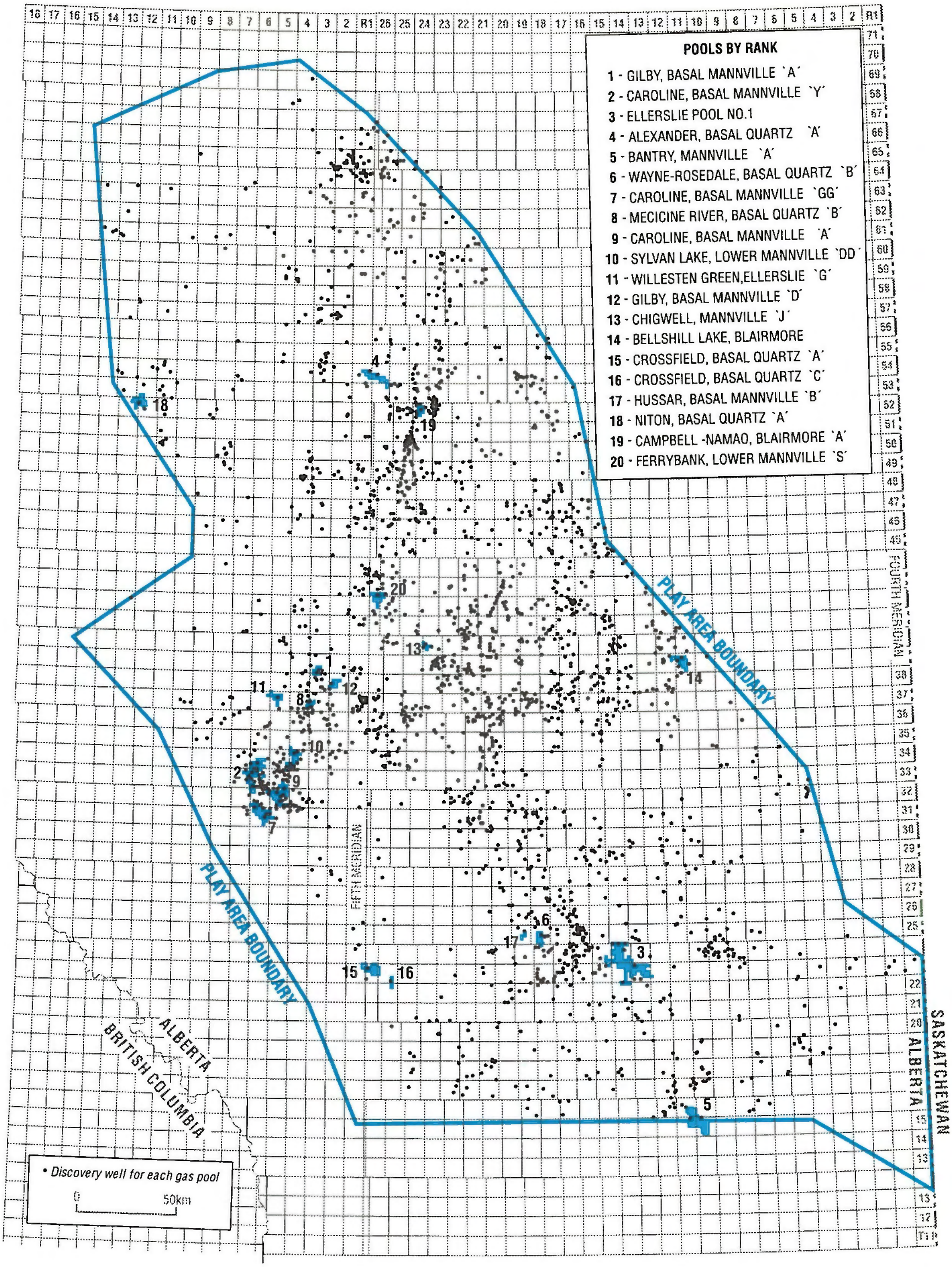


Figure 63. *Play map: central Alberta–Basal Quartz/Ellerslie play.*

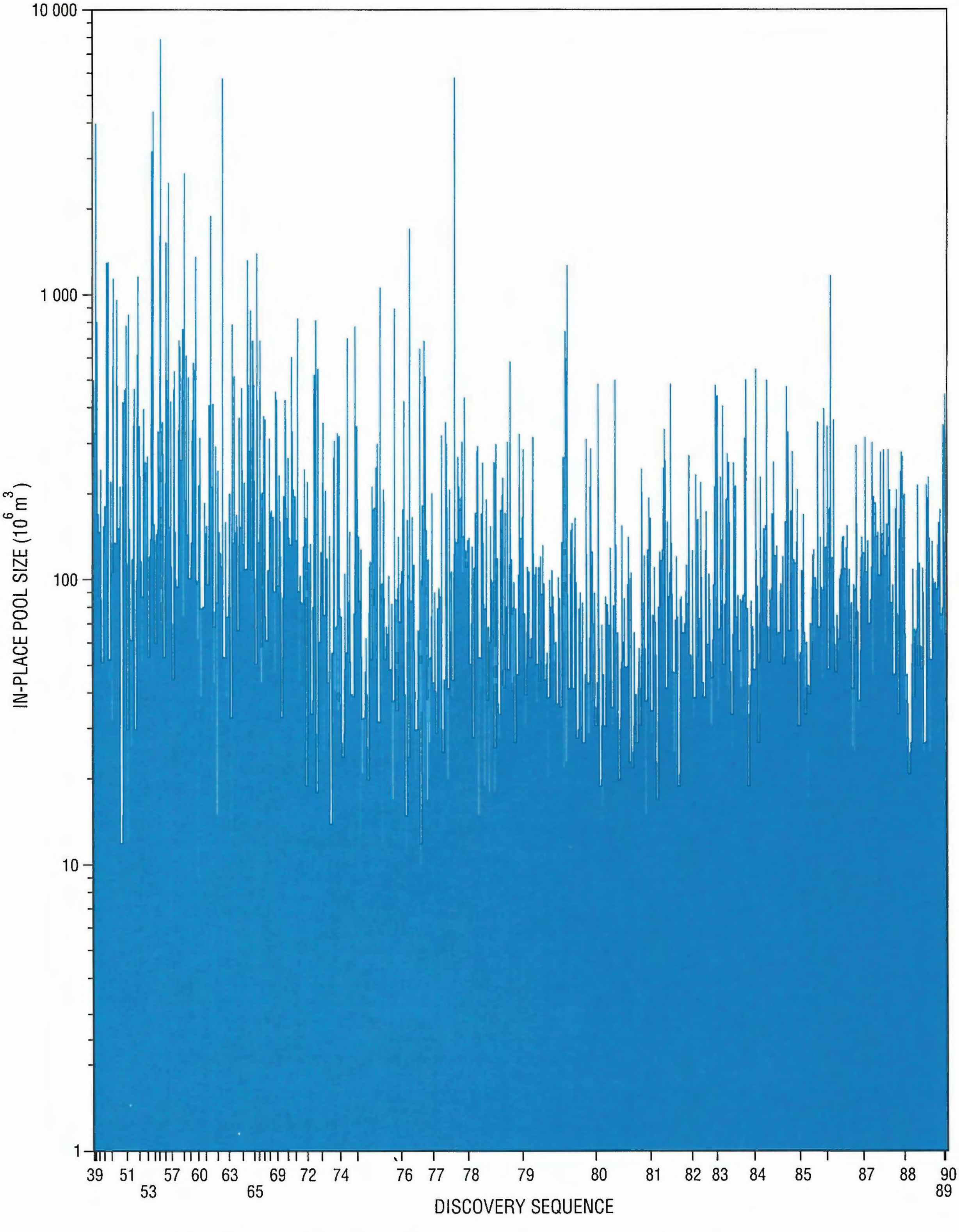


***Figure 64.** Discovery sequence: central Alberta–Basal Quartz/Ellerslie play. Pools listed in Table 13.*

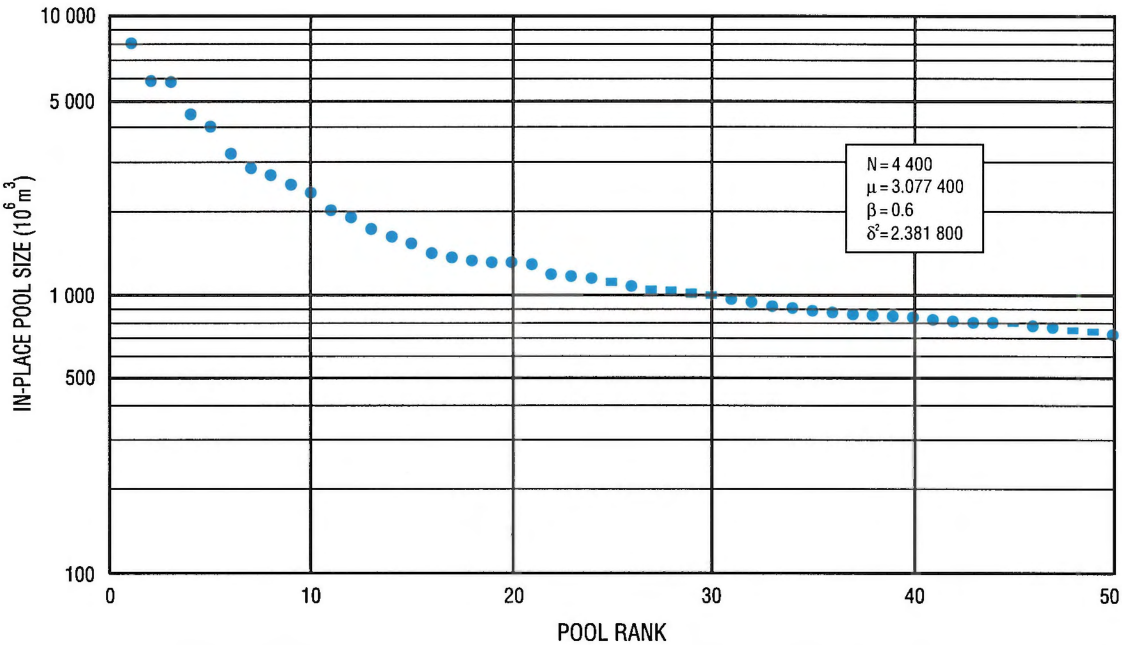


Figure 65. *Pool rank plot: central Alberta–Basal Quartz/Ellerslie play.*

Table 13

Summary of the central Alberta–Basal Quartz/Ellerslie play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Gilby, Basal Mannville A	NA	8 028	1956
2	Caroline, Basal Mannville Y	NA	5 888	1978
3	Ellerslie Pool No. 1	AG	5 834	1963
4	Alexander, Basal Quartz A	NA	4 453	1954
5	Bantry, Mannville A	AG, SG	4 029	1947
6	Wayne–Rosedale, Basal Quartz B	AG, SG	3 229	1954
7	Caroline, Basal Mannville GG	NA	2 855	1969
8	Medicine River, Basal Quartz B	AG, SG	2 706	1959
9	Caroline, Basal Mannville A	NA	2 500	1957
10	Sylvan Lake, Lower Mannville DD	NA	2 330	1963
11	Willesden Green, Ellerslie G	NA	2 033	1964
12	Gilby, Basal Mannville D	NA	1 911	1962
13	Chigwell, Mannville J	NA	1 733	1977
14	Bellshill Lake, Blairmore	AG, SG	1 624	1956
15	Crossfield, Basal Quartz A	NA	1 543	1957
16	Crossfield, Basal Quartz C	NA	1 414	1966
17	Hussar, Basal Mannville B	NA	1 374	1960
18	Niton, Basal Quartz A	AG, SG	1 338	1965
19	Campbell-Namao, Cam Blairmore A	AG, SG	1 312	1950
20	Ferrybank, Lower Mannville S	NA	1 293	1980
Initial in-place volume (discovered) (10^6 m^3)			257 755	
Initial in-place volume (potential) (10^6 m^3)			67 399	
Per cent of play resources undiscovered			21	
Total pools discovered			2 451	
Total pool population			4 400	

NA, nonassociated gas; AG, associated gas; SG, sour gas

Southern Alberta

Upper Mannville/Glauconite play

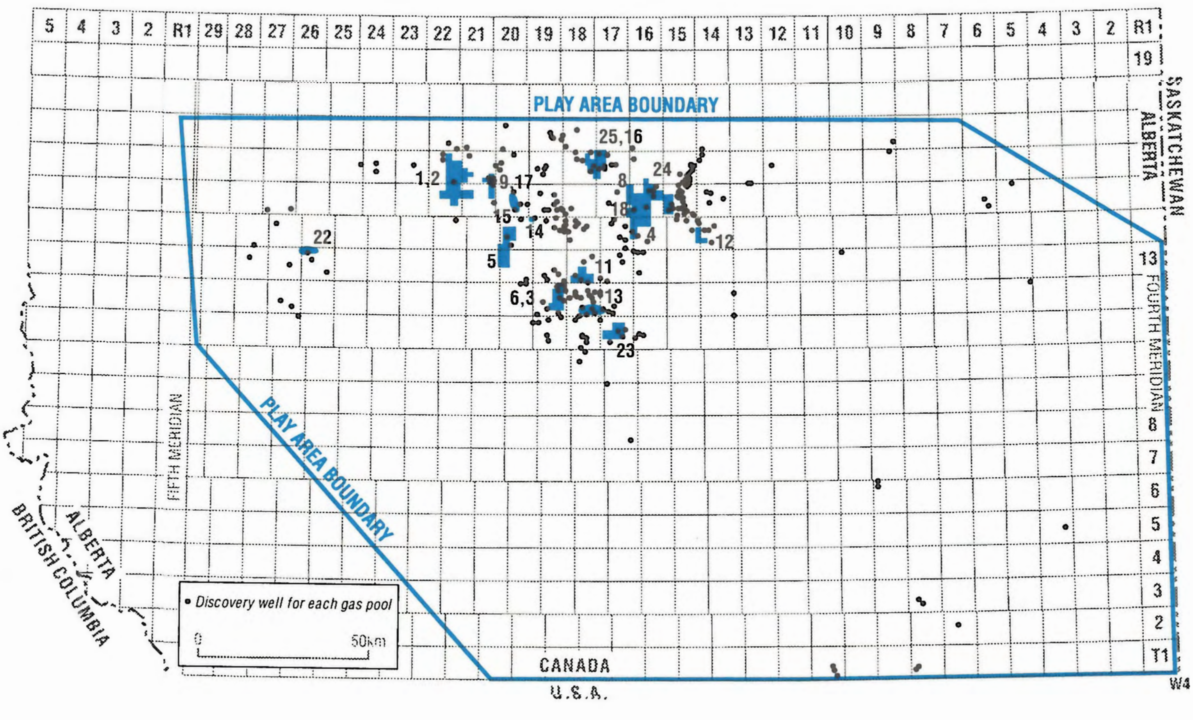
Play definition

This play includes all gas pools and prospects in the Upper Mannville Group and Glauconite Formation in the southern Alberta play area (Fig. 66).

Geology

The Glauconite Formation and Upper Mannville Group have been studied in detail by Wood and Hopkins (1989, 1992) and Wood (1990, 1994), in the Badger, Little Bow, Retlaw, and Turin fields. The Glauconite Formation in southern Alberta unconformably overlies the Ostracod Formation and consists of paleovalley and intervalley deposits. The paleovalley deposits are interpreted to have been deposited in an inner to middle estuarine environment and the intervalley deposits in broad outer estuarine embayments. The fluvial/deltaic deposits of the Upper Mannville Group unconformably overlie the Glauconite Formation. The contact between them is marked by a lithological change from quartzarenites and quartz-rich chertarenites of the Glauconite Formation to lithic arkoses, feldspathic litharenites, and chertarenites of the Upper Mannville Group. This change was interpreted by James (1985) and Wood (1990) to indicate a switch in provenance, probably in response to regional tectonism.

Numerous oil and gas pools have been discovered in southern Alberta, trapped within paleovalley and intervalley deposits of the Glauconite Formation. The fluvial valley-fill deposits of the Upper Mannville Group generally tend to have low permeability and act as effective seals or poor quality reservoirs. The geometry of the valley-fill and intervalley sandstones of the Glauconite Formation are distinctly different. Valley-fill sandstones are thick, elongate bodies, deposited as longitudinal bars in tidal bay-head deltas, whereas intervalley sandstones tend to be thin, sheet sands that formed as a result of the coalescing of sand



POOLS BY RANK

1 - LONG COULEE, GLAUCONITE 'F'
2 - LONG COULEE, GLAUCONITIC 'I'
3 - RETLAW, MANNVILLE 'B'
4 - ENCHANT, UPPER MANNVILLE 'R'
5 - ROBIN, GLAUCONITE 'A'
6 - RETLAW, MANNVILLE 'Y'
8 - ENCHANT, UPPER MANNVILLE 'E'
9 - LONG COULEE, GLAUCONITE 'Z'
11 - RETLAW, MANNVILLE 'RR'
12 - ALDERSON, UPPER MANNVILLE 'LLL'
13 - RETLAW, MANNVILLE 'G2G'
14 - LITTLE BOW, GLAUCONITE
15 - LITTLE BOW, UPPER MANNVILLE 'A'
16 - HECTOR, UPPER MANNVILLE 'C'
17 - LONG COULEE, GLAUCONITE 'W'
18 - ENCHANT, UPPER MANNVILLE 'L'
22 - CLARESHOLMES, GLAUCONITE 'A'
23 - TURIN, UPPER MANNVILLE 'C'
24 - ALDERSON, UPPER MANNVILLE 'DDD'
25 - BADGER, UPPER MANNVILLE 'B'

***Figure 66.** Play map: southern Alberta–Upper Mannville/Glauconite play. Pools listed in Table 14.*

shoals and tidal channel deposits (Wood, 1994). The common updip seals for these reservoirs are: (1) facies changes within the Glauconite, from sandstone to shale, and (2) low-permeability lithic sandstones that fill the cross-cutting Upper Mannville paleovalleys (Wood and Hopkins, 1992). Differential compaction over underlying topographic highs has also played a role in hydrocarbon entrapment.

The Badger Upper Mannville B pool has been described in detail by Wood and Hopkins (1992) and is an example of a reservoir in a Glauconite paleovalley (Figs. 67, 68). It was discovered in 1980 and contains 2350 x 10^3 m^3 of oil-in-place and 418 x 10^6 m^3 of gas-in-place. The updip seal for the reservoir is provided by a younger cross-cutting Upper Mannville valley that is filled by dominantly low-permeability lithic sandstone. Overlying shales within the Glauconite valley-system act as the top seal, and the underlying Ostracod shales and low permeability sandstones of the Sunburst act as the lateral and seat seals for the reservoir. The Badger Upper Mannville B pool is enhanced by differential compaction over an underlying topographic high that provides approximately 7 m of structural closure.

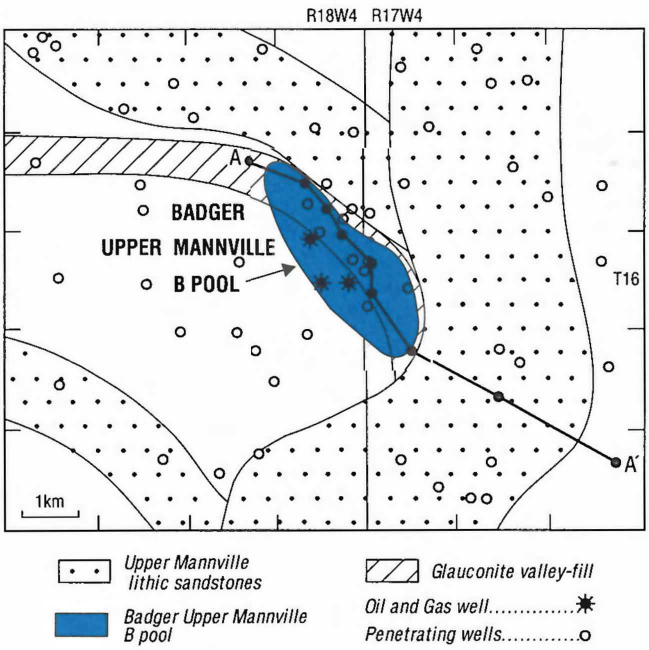


Figure 67. *Example of a hydrocarbon trap in an incised valley in the Glauconite Formation of southern Alberta, the Badger Upper Mannville B pool, as interpreted by J. Wood. The pool is sealed updip by the younger, low permeability, lithic sandstones of the Upper Mannville (modified from Wood and Hopkins, 1992).*

The Retlaw Mannville V pool is an example of a Glauconite intervalley reservoir (Figs. 69, 70) (Wood and Hopkins, 1992). It was discovered in 1971 and has 2210 x 10^3 m^3 of oil-in-place and 154 x 10^6 m^3 gas-in-place. Wood and Hopkins interpret the updip edge of the intervalley sheet sandstones of the Glauconite to be truncated by the younger, lithic, valley-fill sandstones of the Upper Mannville, the latter acting as the updip seal for the reservoir. Shales or muddy sandstones of the intervalley deposits form the lateral, top, and seat seals for the Mannville V pool.

Exploration history

The largest gas pool discovered in the southern Alberta–Upper Mannville/Glauconite play is the Long Coulee Glauconite F pool, discovered in 1967, which contains 2067 x 10^6 m^3 of gas-in-place. A total of 280 gas pools have been discovered in the play and the total discovered gas-in-place for the play is 38 642 x 10^6 m^3 (Figs. 66, 71; Table 14).

Play potential

The estimated expected play potential is 30 312 x 10^6 m^3 of gas-in-place, based on a total pool population of 1300 (Table 14; Fig. 72). This estimate indicates that 44 per cent of the total gas resources for the play remains to be discovered. The largest undiscovered gas pool is predicted to have 901 x 10^6 m^3 of gas-in-place.

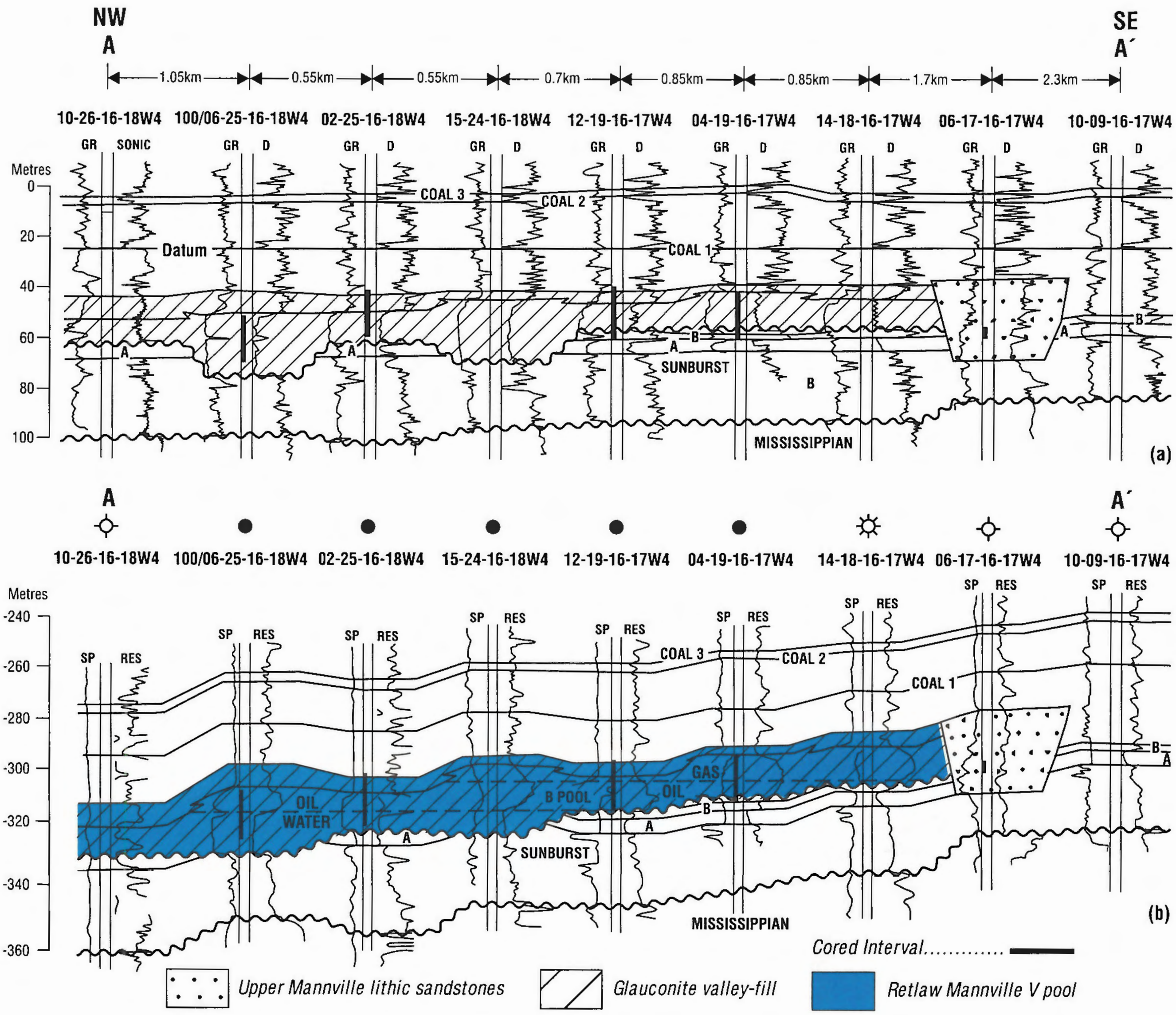


Figure 68. *Stratigraphic a) and structural b) cross-sections across the Badger Upper Mannville B pool (modified from Wood and Hopkins, 1992).*

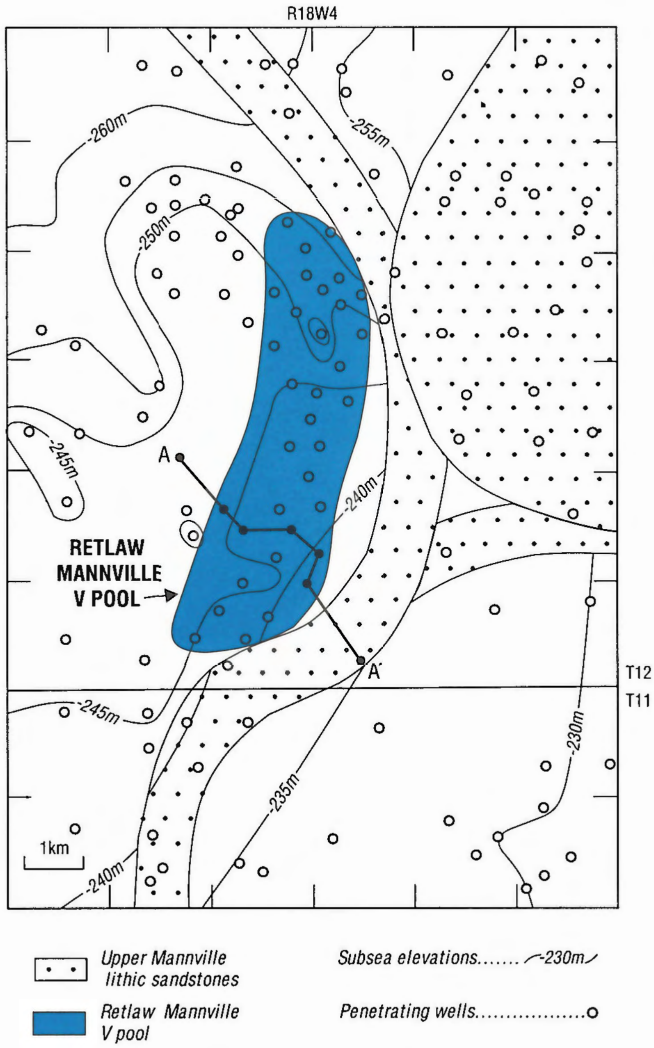


Figure 69. *Example of a hydrocarbon trap in an intervalley deposit, Glauconite Formation of southern Alberta, Retlaw Mannville V pool, as interpreted by J. Wood. The younger, low permeablility, lithic sandstones of the Upper Mannville valley-fill form the seal for the reservoir (modified from Wood and Hopkins, 1992).*

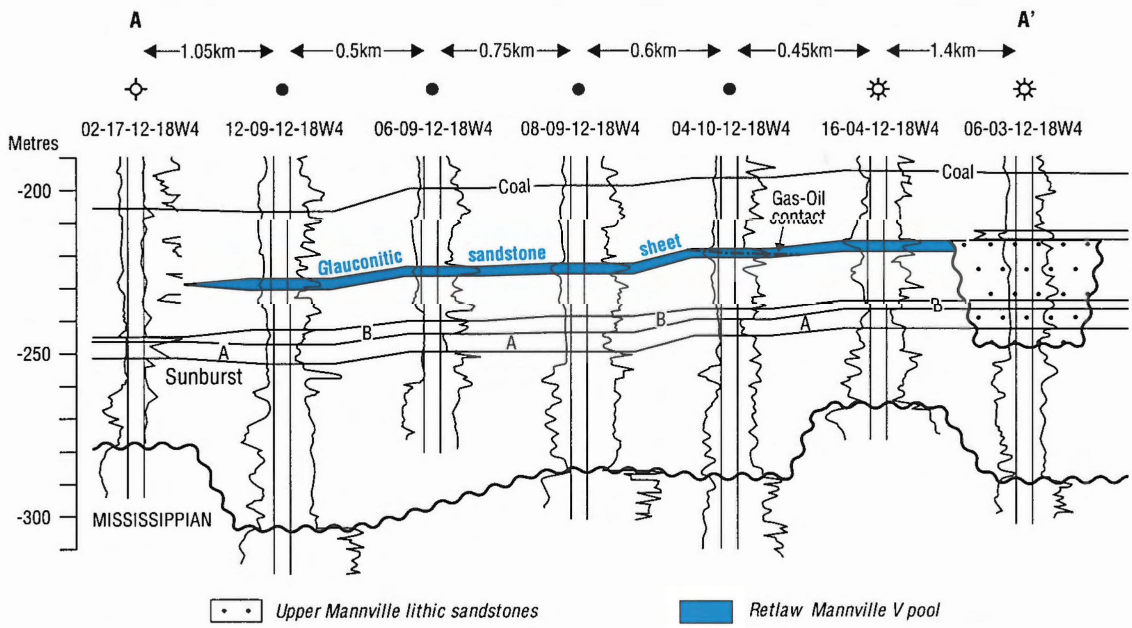


Figure 70. *Structural cross-section across the Retlaw Mannville V pool. Note truncation of the glauconite sheet sandstone, shown grey, by the younger, low permeability, lithic sandstones of the Upper Mannville valley-fill (modified from Wood and Hopkins, 1992).*

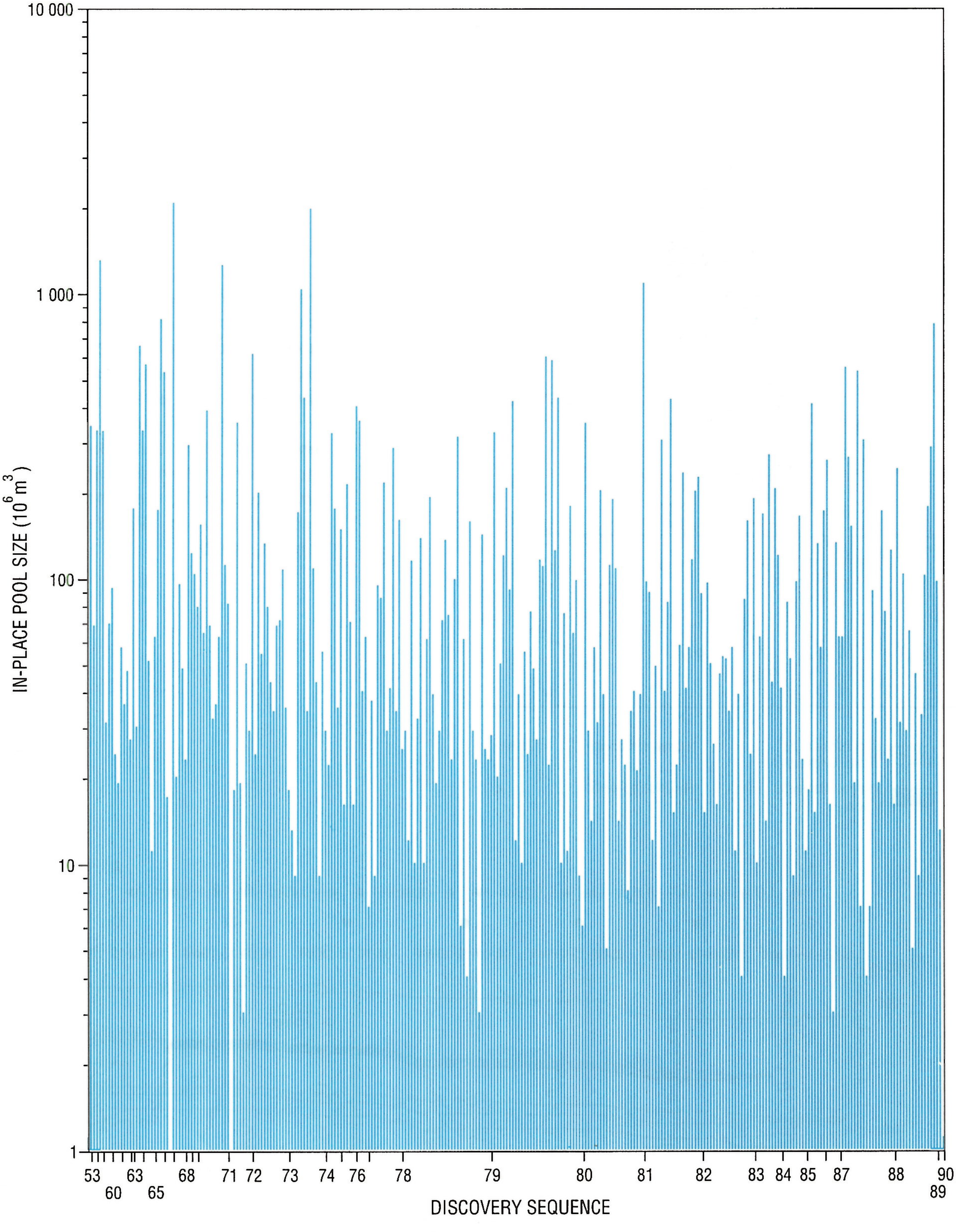


Figure 71. Discovery sequence: southern Alberta–Upper Mannville/Glauconite play.

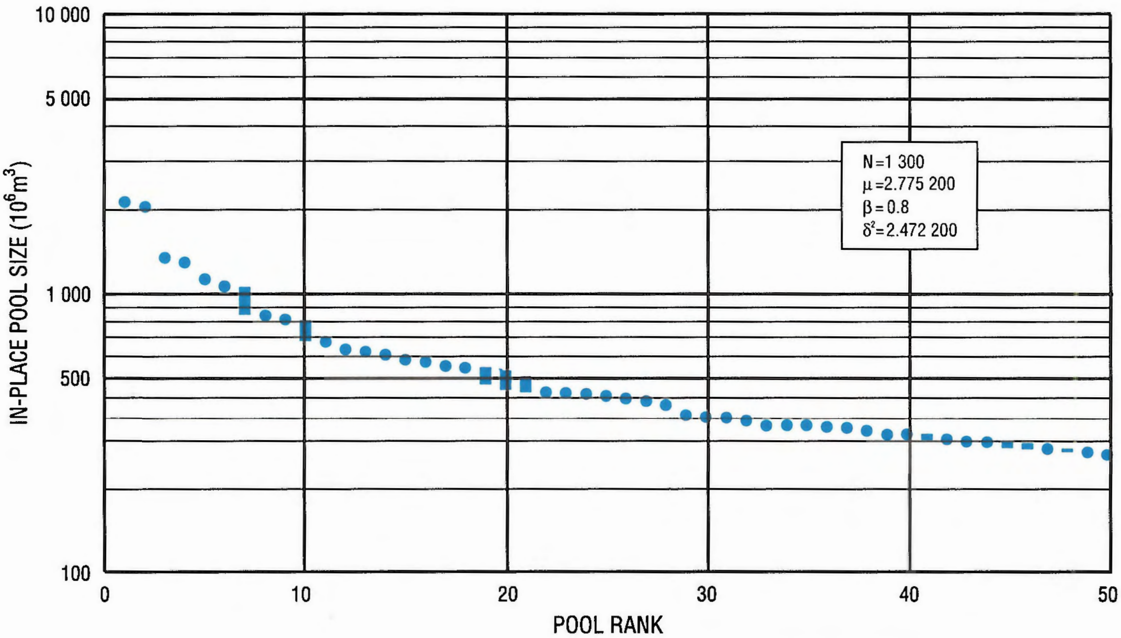


Figure 72. *Pool rank plot: southern Alberta–Upper Mannville/Glauconite play.*

Table 14

Summary of the southern Alberta–Upper Mannville/Glauconite play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Long Coulee, Glauconite F	AG, SG	2 067	1967
2	Long Coulee, Glauconitic I	NA	1 971	1974
3	Retlaw, Mannville B	AG	1 299	1959
4	Enchant, Upper Mannville R	NA	1 250	1971
5	Robin, Glauconite A	NA	1 084	1981
6	Retlaw, Mannville Y	NA	1 030	1974
8	Enchant, Upper Mannville E	NA	808	1966
9	Long Coulee, Glauconite Z	NA	781	1989
11	Retlaw, Mannville RR	AG, SG	651	1964
12	Alderson, Upper Mannville LLL	NA	611	1972
13	Retlaw, Mannville G2G	AG	599	1980
14	Little Bow, Glauconite	NA	582	1980
15	Little Bow, Upper Mannville A	NA	560	1965
16	Hector, Upper Mannville C	NA	550	1988
17	Long Coulee, Glauconite W	NA	533	1988
18	Enchant, Upper Mannville L	NA	527	1966
22	Claresholm, Glauconite A	NA	430	1980
23	Turin, Upper Mannville C	AG, SG	429	1974
24	Alderson, Upper Mannville DDD	NA	425	1982
25	Badger, Upper Mannville B	AG, SG	418	1980
Initial in-place volume (discovered) (10^6 m^3)			38 642	
Initial in-place volume (potential) (10^6 m^3)			30 312	
Per cent of play resources undiscovered			44	
Total pools discovered			280	
Total pool population			1 300	

NA, nonassociated gas; AG, associated gas; SG, sour gas

Ostracod/Lower Mannville play

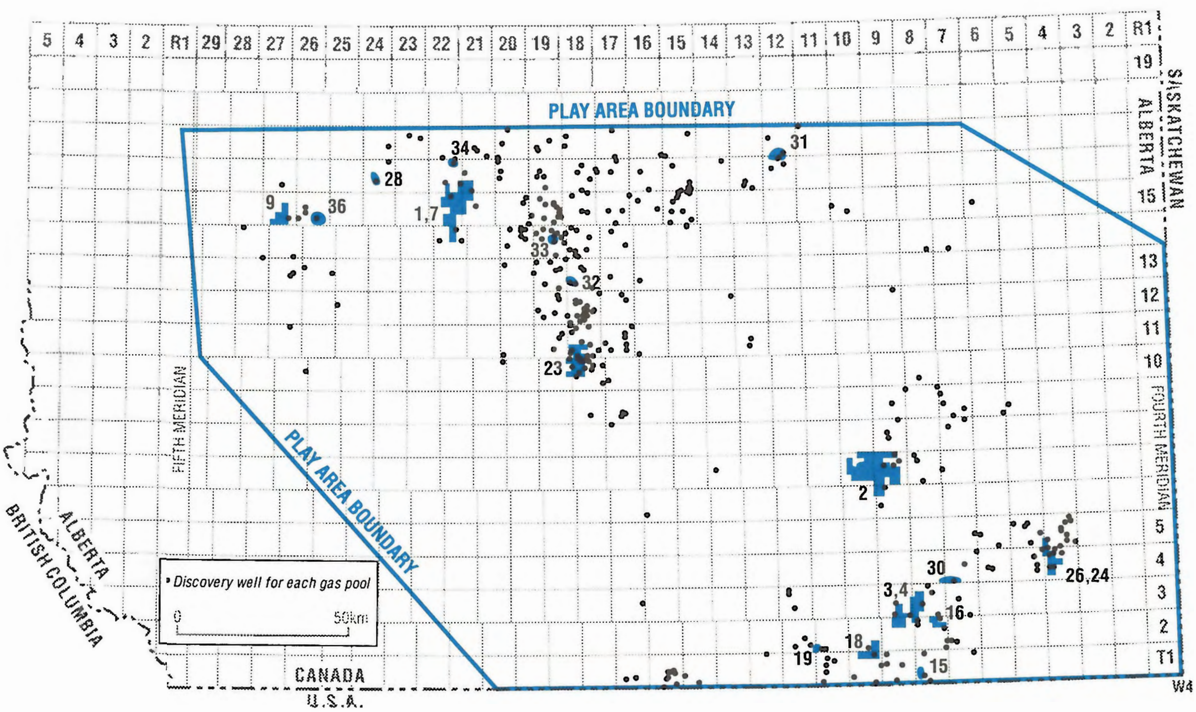
Play definition

This play includes all gas pools and prospects contained in the Ostracod Member and Lower Mannville Group in the southern Alberta play area (Fig. 73). The Ostracod pools were combined with the Lower Mannville Group in this play because of correlation problems encountered in the pool database.

Geology

The Lower Mannville Group in southern Alberta consists of fluvial to shallow-marine sediments deposited during the southward transgression of the Boreal Sea. Deposition of the Lower Mannville Group was strongly influenced by the topography of the basal unconformity, particularly on the Swift Current Platform in the east. The Lower Mannville Group unconformably overlies units ranging from Upper Palaeozoic to lowermost Lower Cretaceous. Erosion during the latest Jurassic and earliest Cretaceous created large incised valley systems that cut into the underlying Jurassic units. The basal parts of some valleys are known to contain remnants of Upper Jurassic strata (Farshori and Hopkins, 1989). The two most prominent valley systems in southern Alberta are the Whitlash and Cutbank valleys that trend in a north-northwest direction (Fig. 74).

The Cutbank Formation is the lowermost unit defined in the Mannville Group in southern Alberta and has been studied in detail by Hayes (1982). He described the Cutbank as a medium to coarse grained, poorly sorted, litharenite to extralitharenite. Hayes interpreted it to have been deposited in a fluvial environment. The Cutbank Formation is found only in the western portion of Hayes' study area (Fig. 75) (Twp 4-20, Rge 2-14W4) and is primarily confined to the Cutbank Valley system. The eastern margin of this valley system has been delineated by Hayes (1982) and is illustrated in Figure 75. Smaller tributary valleys breach the eastern margin of the Cutbank Valley and minor hydrocarbon reservoirs have been discovered



POOLS BY RANK

1 - LONG COULEE, SUNBURST 'G'
2 - FORTY MILE, LOWER MANNVILLE 'E'
3 - PENDANT D'OREILLE, MANNVILLE 'C'
4 - PENDANT D'OREILLE, MANNVILLE 'A'
7 - LONG COULEE, SUNBURST 'D'
9 - PARKLAND NORTHEAST, LOWER MANNVILLE 'A'
15 - BLACK BUTTE, SUNBURST - SWIFT 'A'
16 - PENDANT D'OREILLE, MANNVILLE 'H'
18 - LAIT, LOWER MANNVILLE 'A'
19 - KNAPPEN, LOWER MANNVILLE 'G'
23 - TURIN, LOWER MANNVILLE 'H'
24 - MANYBERRIES, SUNBURST 'R'
26 - MANYBERRIES, SUNBURST 'O'
28 - VULCAN, BASAL MANNVILLE 'A'
30 - PENDANT D'OREILLE, MANNVILLE 'E'
31 - BANTRY, MANNVILLE 'G'
32 - RETLAW, MANNVILLE 'G'
33 - LITTLE BOW, LOWER MANNVILLE 'D'
34 - LONG COULEE, SUNBURST 'C'
36 - PARKLAND NORTHEAST, LOWER MANNVILLE 'D'

Figure 73. *Play map: southern Alberta–Ostracod/Lower Mannville play. Pools listed in Table 15.*

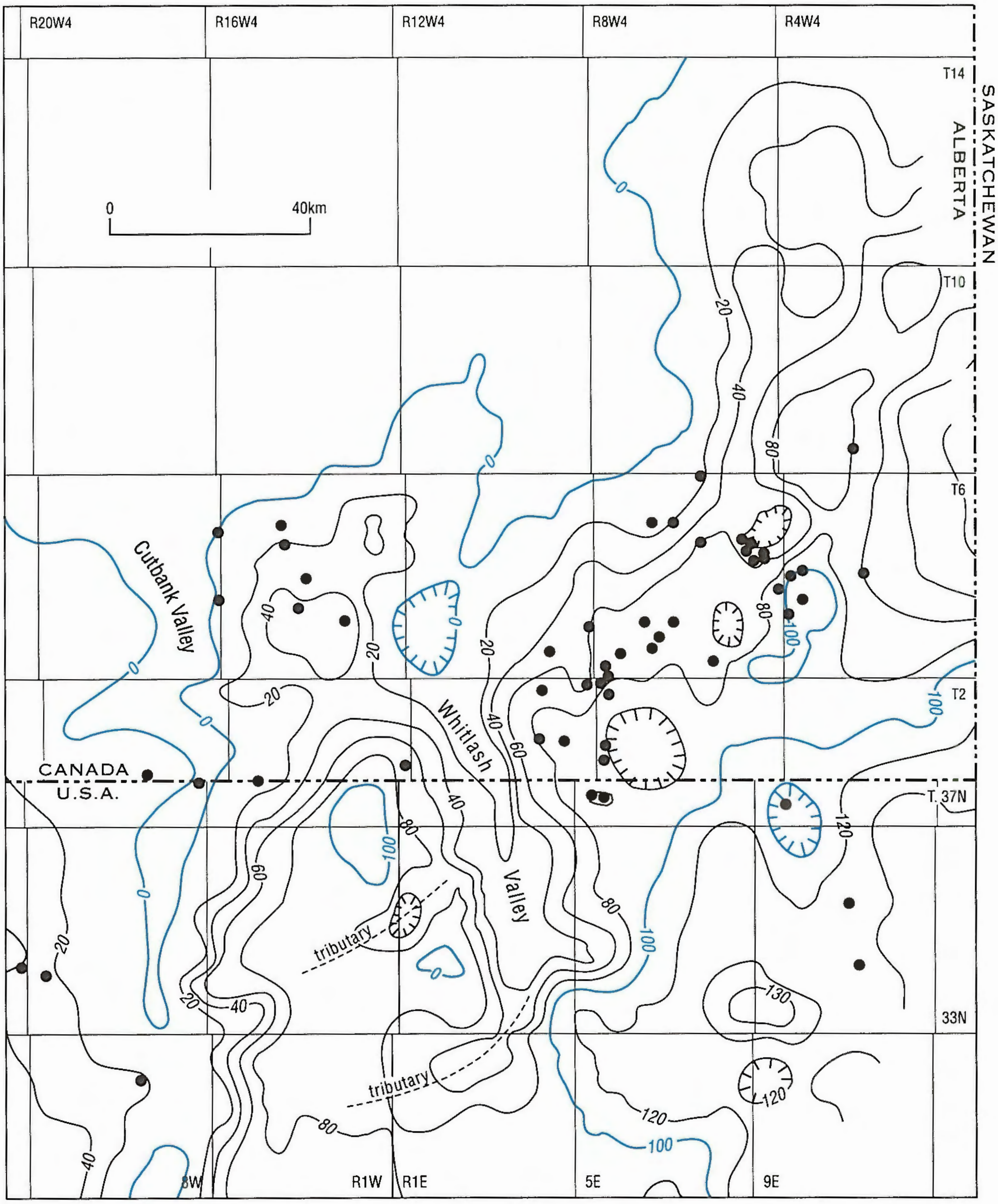


Figure 74. *Isopach map of the Jurassic Swift Formation, southern Alberta, illustrating the locations of the Cutbank and Whitlash valley systems (modified from Hayes, 1982). Contour interval = 20 feet.*

within them (i.e., Chin Coulee, Oyibo, 1972; and Horsefly Lake, Figs. 76, 77).

The Sunburst Member unconformably overlies the Cutbank Formation, or where the latter is absent, rests on older units. Farshori and Hopkins (1989) recognized that two distinct types of sandstone bodies, ribbon and sheet sandstones, occur within the Sunburst Member of southern Alberta (Twp 8-31, Rge 8-24W4) and that they represent two different depositional systems. The ribbon sandstones consist of pebbly, coarse to fine-grained chertarenite, sublitharenite, and minor quartzarenite, and siltstones, deposited in fining-upward sequences up to 30 m thick. They are interpreted to have been deposited as point-bars in a fluvial-channel system. The sheet sandstones are composed of single, or stacked, coarsening-upward cycles of lenticular to wavy bedded, ripple and parallel laminated, fine to very fine-grained quartzarenite and sublitharenite. The coarsening-upward cycles are up to 20 m thick and are interpreted as prograding, shallow-marine, shoreface units, deposited along a low-energy, wave-dominated shoreline. Hydrocarbon reservoirs have been found within both the ribbon (Alderson East, Figs. 78, 79) and sheet (Twining, Figs. 80, 81) sandstones of the Sunburst Member. Reservoirs within the sheet sandstones are characterized by relatively

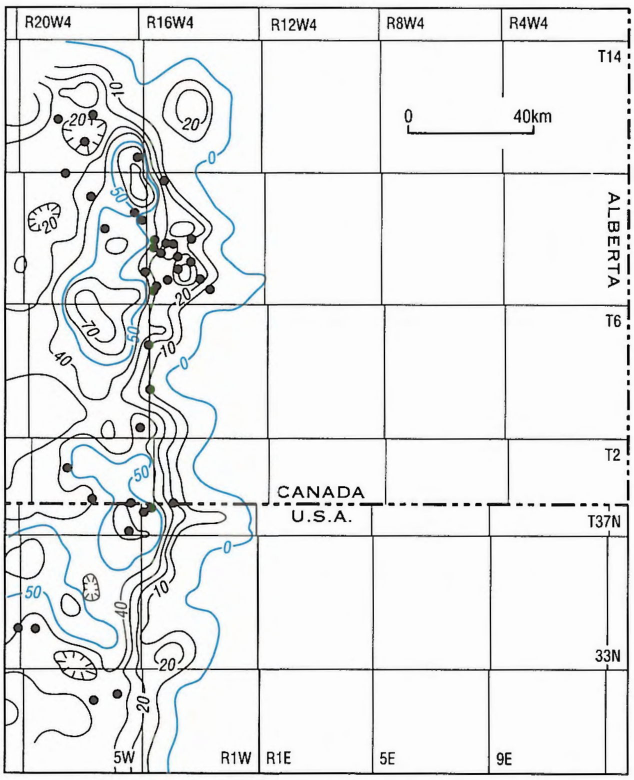


Figure 75. Isopach map of the Cutbank Formation, southern Alberta (modified from Hayes, 1982). Contour interval = 20 feet.

uniform, fine grained, quartzose sandstones in laterally continuous sandstones bodies. The trapping mechanism is either structural, due to differential compaction over underlying highs on the unconformity surface, or stratigraphic, where the sheet sandstones have been cross-cut by mudstone filled channels. Hydrocarbon reservoirs in the ribbon sandstones are more heterogeneous than the sheet sandstone reservoirs. They tend to have low permeability zones due to the presence of intergranular kaolinite and shale clasts derived from the underlying Cutbank Formation. Reservoirs in the ribbon sandstones occur within the quartzose sandstones.

The Ostracod Member overlies the Sunburst Member and marks the maximum southward transgression of the Boreal Sea. The Ostracod Member has been subdivided into four units, (Farshori and Hopkins, 1989), referred to as units A to D, in chronostratigraphic order. Units A and B are the Bantry shale and Ostracod limestone, respectively, and are distinct stratigraphic markers that can be traced across southern Alberta. Units C and D represent an overall coarsening-upward succession, grading up from interbedded siltstones and shales (C) to feldspathic sandstones (D). The complete Ostracod succession in the Little Bow area is approximately 20 m thick. The top of the Ostracod marks a major shift in the depositional pattern of the Mannville Group, changing from transgressive to regressive. The Ostracod is overlain by the progradational coastal and continental deposits of the Upper Mannville.

Exploration history

The largest gas pool discovered in the southern Alberta-Ostracod Member/Lower Mannville Group play is the Long Coulee Sunburst G pool. The Long Coulee Sunburst G pool was discovered in 1960 and has 2666 x 10^6 m^3 of gas-in-place. There have been 386 gas pools discovered in the play and the total discovered gas-in-place is 30 508 x 10^6 m^3 (Figs. 82, 83; Table 15).

Play potential

The estimated expected play potential is 12 005 x 10^6 m^3 of gas-in-place, based on a total pool population of 750 (Table 15; Fig. 83). The largest undiscovered gas pool is predicted to have 1046 x 10^6 m^3 of gas-in-place. Based on this estimate 28 per cent of the total gas resources for this play remains to be discovered.

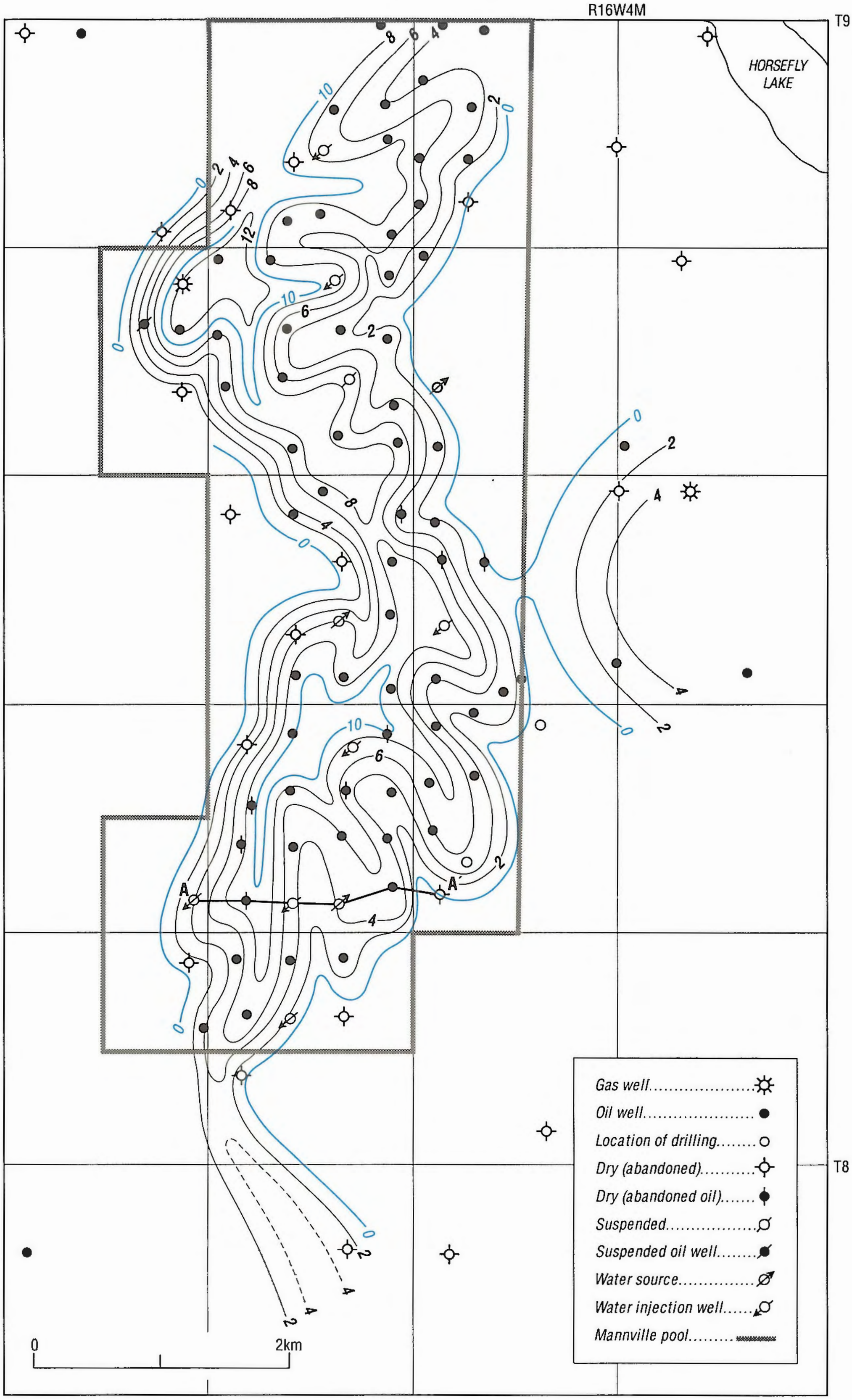


Figure 76. *Horsefly Lake Mannville pool, net pay map (modified from Gallad, 1991).*

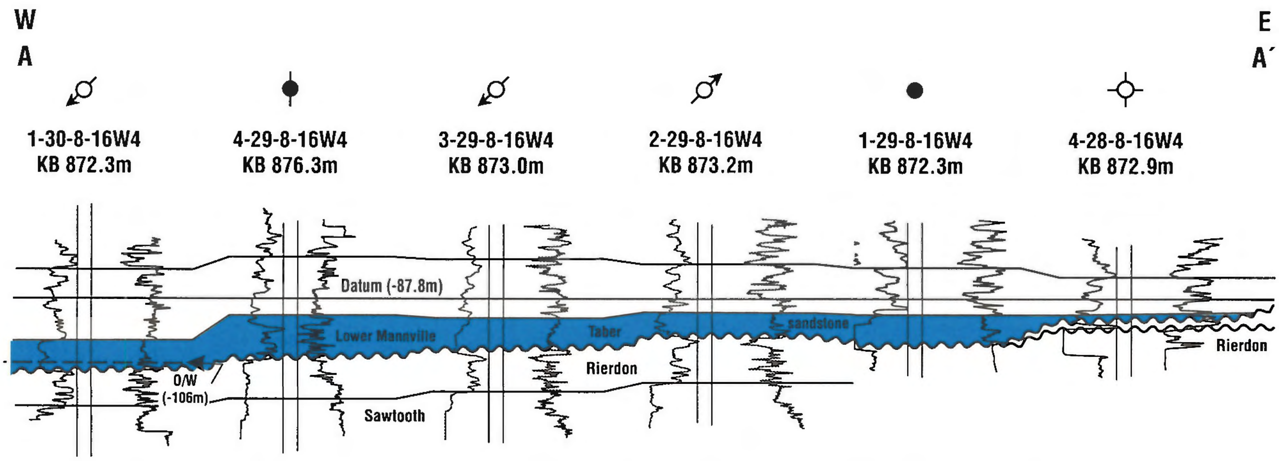


Figure 77. *Structural cross-section across the Horsefly Lake Mannville pool (modified from Gallad, 1991).*

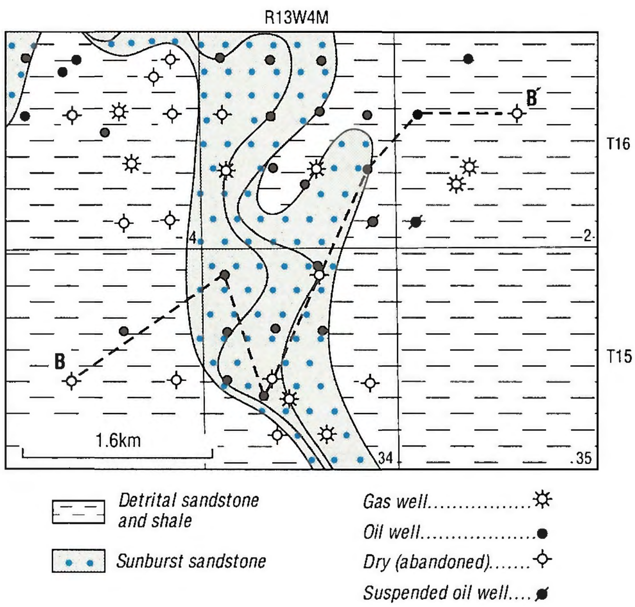


Figure 78. *Sunburst ribbon sandstone in the Alderson East area. The Sunburst ribbon sandstones are hydrocarhon bearing and truncate the generally unproductive sandstone and shale of the Detrital Member (modified from Farshori and Hopkins, 1989).*

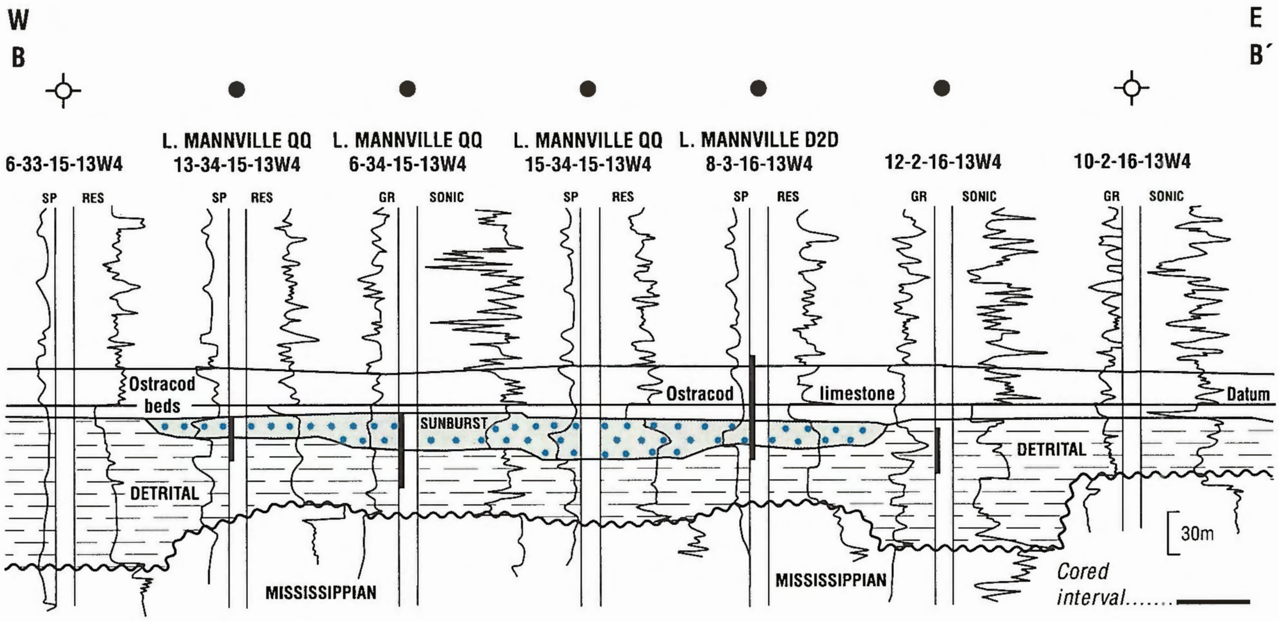


Figure 79. *Cross-section illustrating the relations between the Sunburst and Detrital in the Alderson East field area (modified from Farshori and Hopkins, 1989).*

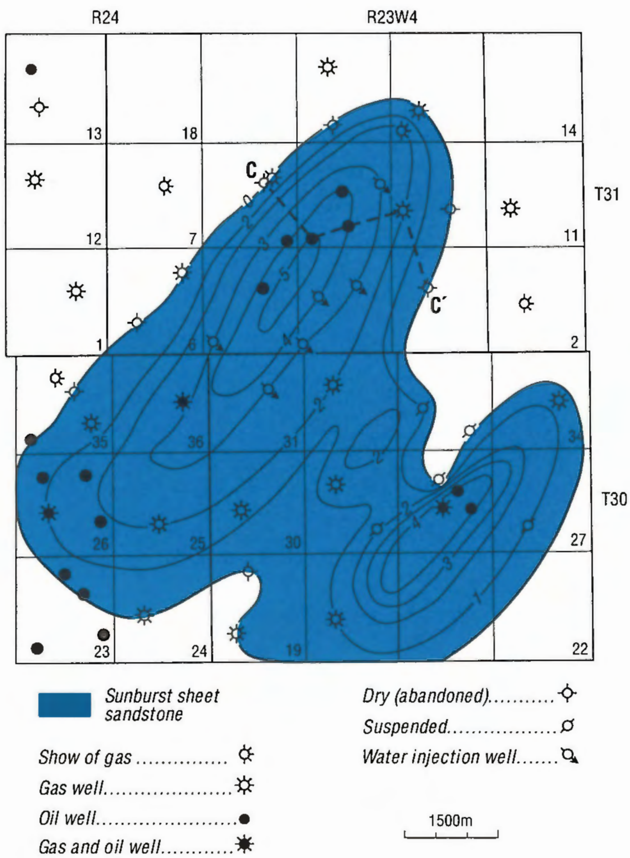


Figure 80. *Isopach map of the Sunburst sheet sandstone in the Twining area. Contour interval = 1 m (modified from Farshori and Hopkins, 1989).*

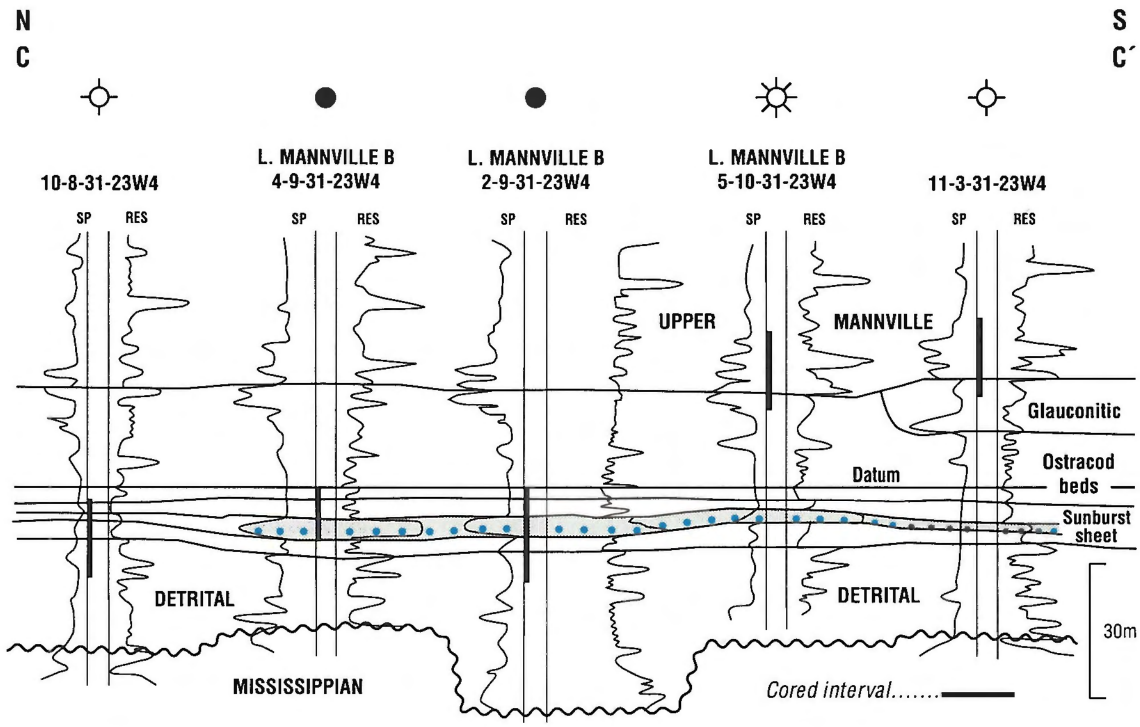


Figure 81. *Cross-section through the Twining area showing the lateral terminations of the Sunburst sheet sandstone. Oil is trapped at the updip margin of the porous Sunburst sandstone (modified from Farshori and Hopkins, 1989).*

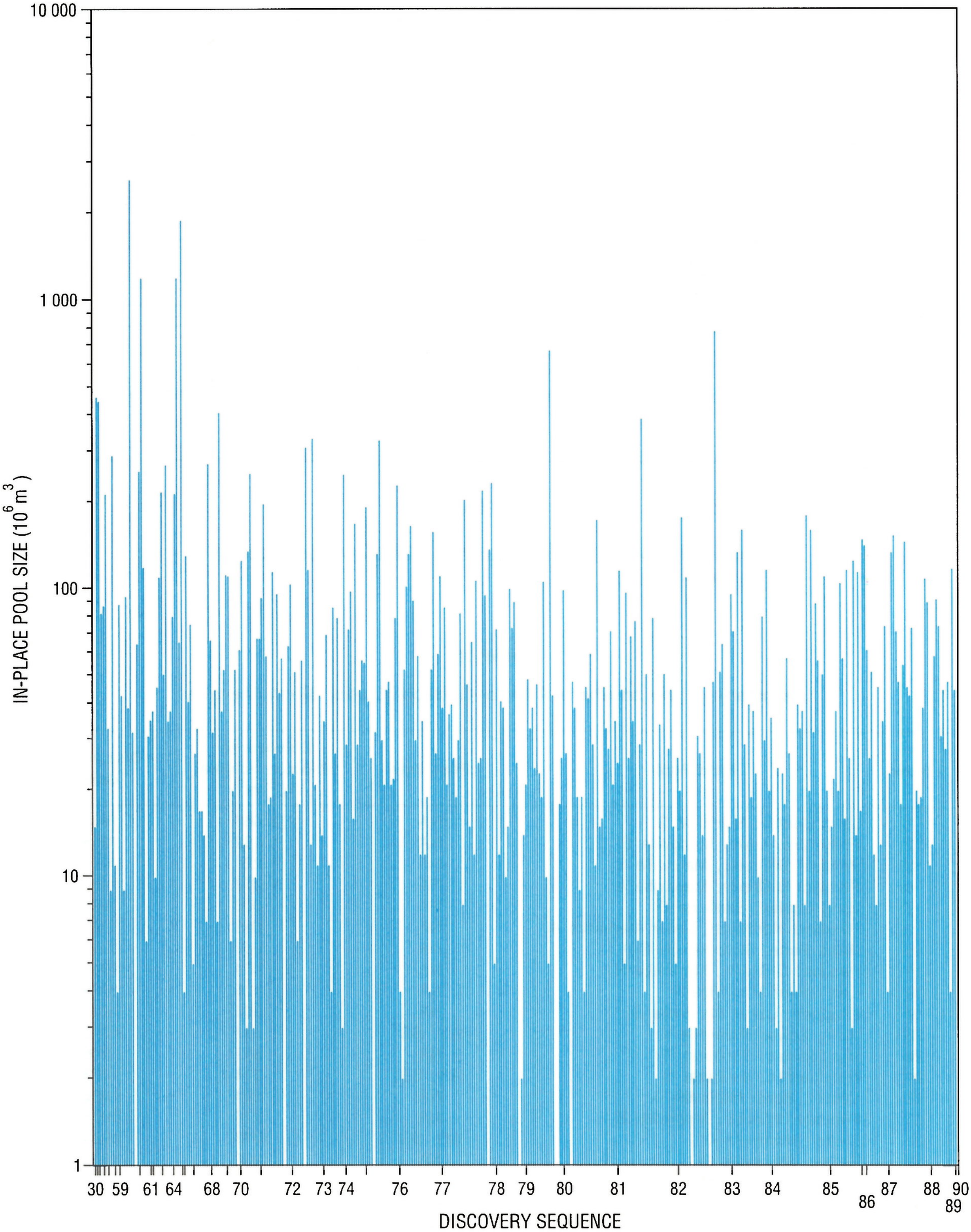


***Figure 82.** Discovery sequence: southern Alberta–Ostracod/Lower Mannville play.*

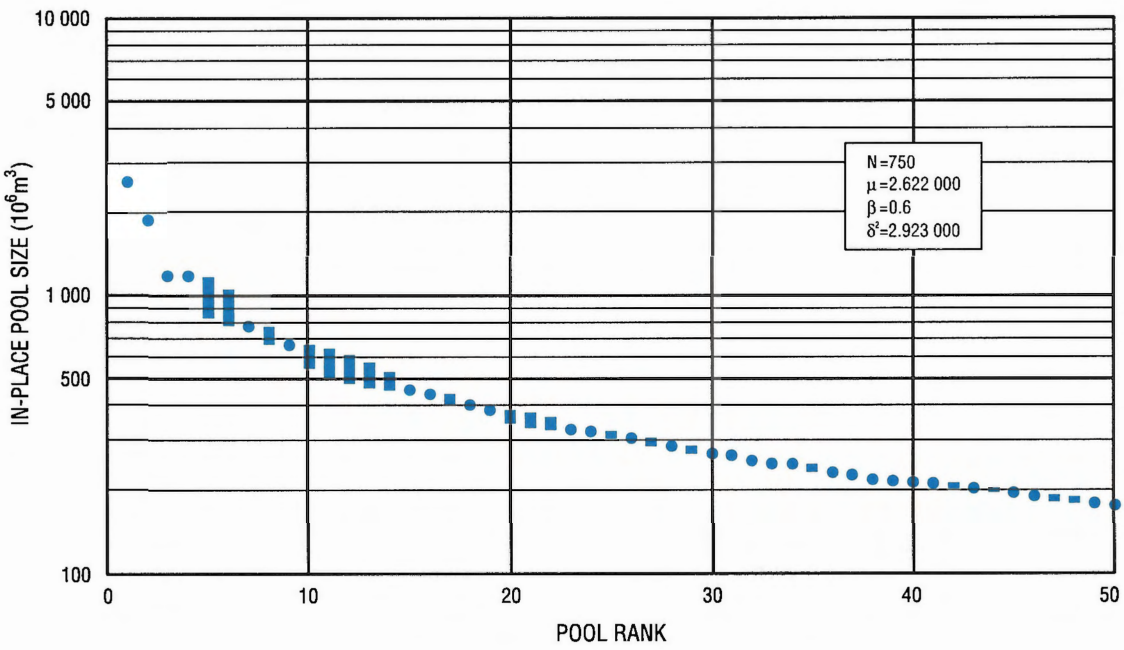


Figure 83. *Pool rank plot: southern Alberta–Ostracod/Lower Mannville play.*

Table 15

Summary of the southern Alberta–Ostracod/Lower Mannville play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
1	Long Coulee, Sunburst G	NA	2 666	1960
2	Forty Mile, Lower Mannville E	NA	1 932	1965
3	Pendant D'Oreille, Mannville C	NA	1 220	1965
4	Pendant D'Oreille, Mannville A	NA	1 217	1961
7	Long Coulee, Sunburst D	NA	800	1982
9	Parkland Northeast, Lower Mannville A	NA	685	1979
15	Black Butte, Sunburst-Swift A	NA	469	1943
16	Pendant D'Oreille, Mannville H	NA	454	1946
18	Lait, Lower Mannville A	NA	415	1969
19	Knappen, Lower Mannville G	NA	396	1981
23	Turin, Lower Mannville II	AG, SG	337	1973
24	Manyberries, Sunburst R	NA	332	1976
26	Manyberries, Sunburst O	AG, SG	314	1973
28	Vulcan, Basal Mannville A	NA	294	1956
30	Pendant D'Oreille, Mannville E	NA	276	1968
31	Bantry, Mannville G	AG, SG	273	1964
32	Retlaw, Mannville G	NA	260	1960
33	Little Bow, Lower Mannville D	NA	255	1971
34	Long Coulee, Sunburst C	AG, SG	253	1974
36	Parkland Northeast, Lower Mannville D	NA	237	1978
Initial in-place volume (discovered) (10^6 m^3)			30 508	
Initial in-place volume (potential) (10^6 m^3)			12 005	
Per cent of play resources undiscovered			28	
Total pools discovered			386	
Total pool population			750	

NA, nonassociated gas; AG, associated gas; SG, sour gas

Alberta and Saskatchewan

Detrital play

Play definition

This play includes all gas pools and prospects contained within the Detrital and Deville formations in the Alberta and Saskatchewan play area (Fig. 84).

Geology

As mentioned previously, the Detrital, or Deville Formation is an accumulation of weathering products lying directly on Palaeozoic rocks, and separated from the rest of the Mannville Group by an unconformity (Christopher, 1974). It occurs very irregularly throughout much of the basin but it is unclear whether this patchy occurrence is dominantly the result of sub-Mannville erosion or nondeposition. In some places it lies in depressions on the unconformity surface, but in others, it forms the upper part of highstanding areas. The unit consists of nonmarine sandstone, mudstone, and some chert-pebble conglomerate, some of which show evidence for transport (i.e., crossbedding), hence it is not entirely an *in-situ* accumulation. It is not well dated, and may differ in age from place to place. Because of these uncertainties about the unit, all the gas pools within it have been grouped into a single play. Pools occur as stratigraphic entrapments against paleotopography on the basal unconformity.

Exploration history

A total of 193 gas pools has been discovered in the Alberta and Saskatchewan–Detrital play and the total gas-in-place for the play is 11 432 x 10^6 m^3 (Figs. 84, 85; Table 16). The largest gas pool in the play is the Provost Lower Mannville EE pool, which has 750 x 10^6 m^3 of gas-in-place and was discovered in 1984.

Play potential

The estimated expected play potential is 33 563 x 10^6 m^3 of gas-in-place, based on a total pool population of 1200 (Table 16; Fig. 86). This estimate indicates that 75 per cent of the total gas resources for this play remains to be discovered. The largest undiscovered gas pool for this play is predicted to be the largest pool in the play and is estimated to have 966 x 10^6 m^3 of gas-in-place.

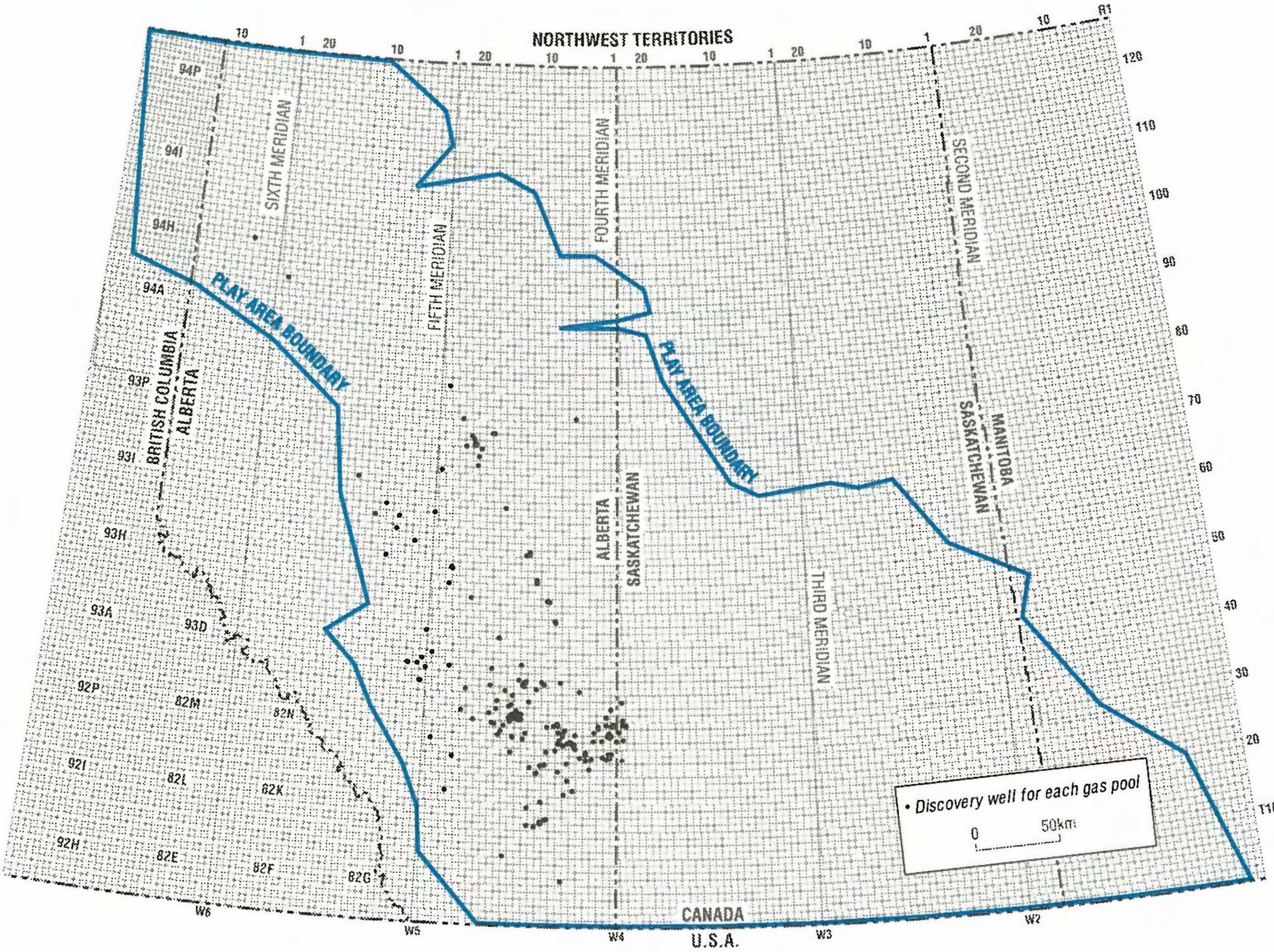


Figure 84. Play map: Alberta and Saskatchewan–Detrital play. Pools listed in Table 16.

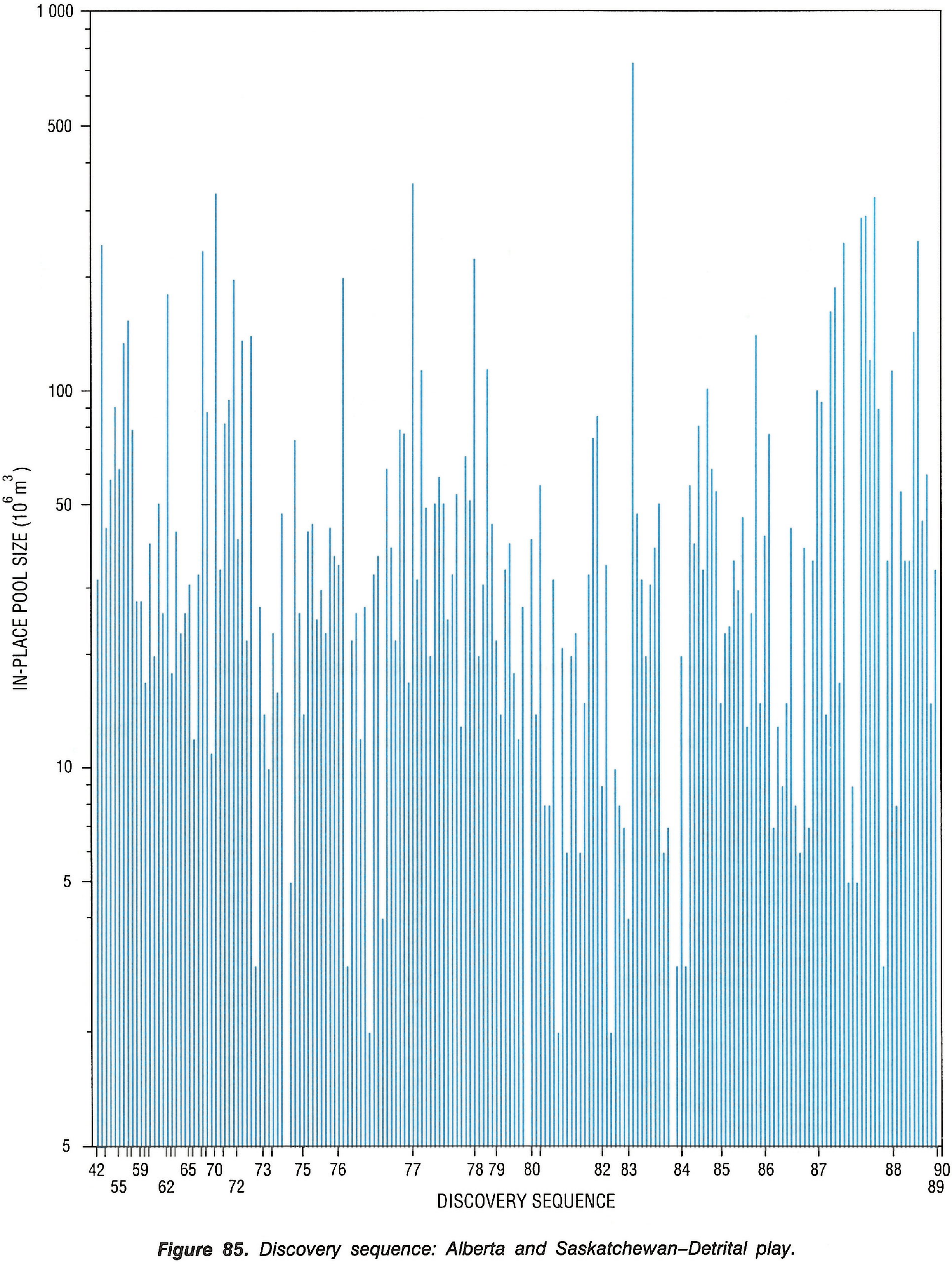


Figure 85. *Discovery sequence: Alberta and Saskatchewan–Detrital play.*

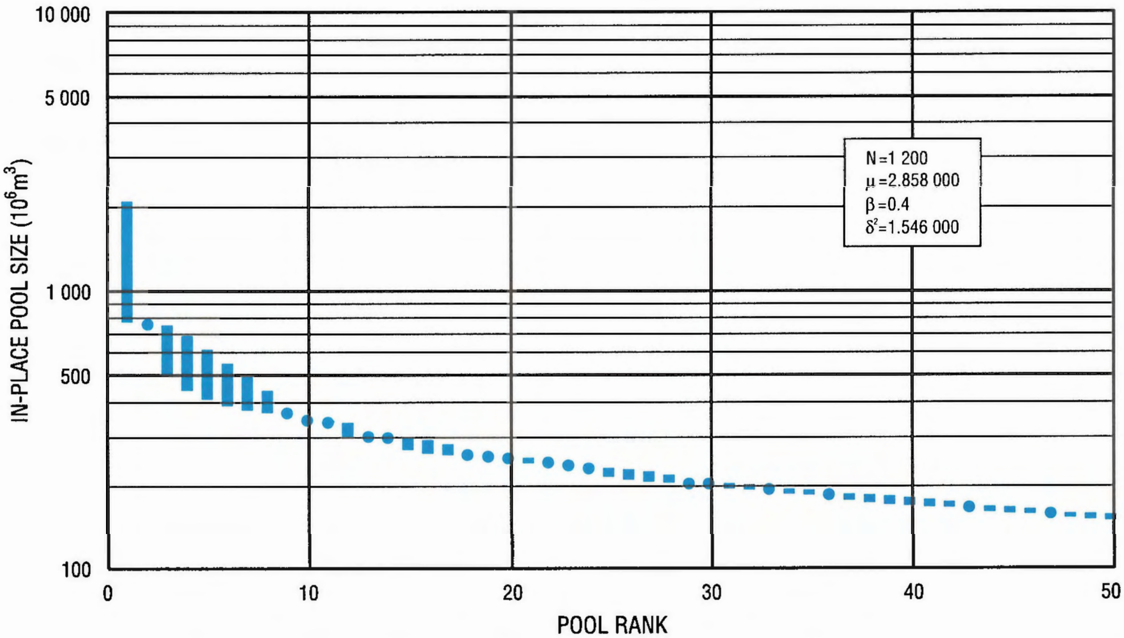


Figure 86. *Pool rank plot: Alberta and Saskatchewan-Detrital play.*

Table 16

Summary of the Alberta and Saskatchewan-Detrital play

Rank	Field/Pool	Pool type	Discovered in-place volume (10^6 m^3)	Discovery date
2	Provost, Lower Mannville EE	NA	750	1984
9	Cessford, Detrital A	NA	360	1977
10	Willingdon, Mannville FF	NA	338	1970
11	Heathdale, Lower Mannville	NA	332	1988
13	Hudson, Detrital B	NA	296	1988
14	Gilby, Detrital	NA	292	1988
18	Capron, Detrital B	NA	254	1989
19	Capron, Detrital A	NA	251	1988
20	Acheson, Detrital A	NA	247	1951
22	Sedalia, Lower Mannville B	NA	238	1968
23	Capron, Detrital C	NA	232	1990
24	Heathdale, Detrital	NA	227	1978
29	Stanmore, Lower Mannville W	NA	202	1977
30	Hudson, Mannville	NA	200	1972
33	Heathdale, Lower Mannville E	NA	191	1988
36	Sylvan Lake, Detrital D	NA	183	1962
43	Benton, Detrital	NA	165	1988
47	Virginia Hills, Lower Blairmore	NA	156	1956
53	Benton, Detrital	NA	146	1989
54	Ghost Pine, Lower Mannville W	NA	143	1986
Initial in-place volume (discovered) (10^6 m^3)			11 432	
Initial in-place volume (potential) (10^6 m^3)			33 563	
Per cent of play resources undiscovered			75	
Total pools discovered			193	
Total pool population			1 200	

NA, nonassociated gas

Saskatchewan

Cantuar play

Play definition

This play includes all gas pools and prospects in the Cantuar Formation of Saskatchewan.

There are only four gas pools discovered to date in the Saskatchewan-Cantuar play. This play is considered an immature play for assessment purposes.

Geology

The Cantuar is equivalent to the entire Mannville in Alberta and comprises three members (McLeod, Dimmock Creek, and Atlas). Correlation of these stratigraphic units into southern Alberta and to the north, into the Lloydminister area is as yet unclear. The regional geology of the unit has been described by Christopher (1974, 1984), Putnam (1989), and Leckie et al. (1994). At the base of the Cantuar is a major unconformity that downcuts as much as 74 m into the underlying Jurassic units. The Dimmock Creek and McLeod members are found only at the base of the valley-fills and the Atlas Member is deposited within the valleys and overlying the interfluve areas capped by the Jurassic Success S2. Because this was an area of low subsidence rate, it is generally nonmarine to marginal marine, with numerous incised valleys filled by estuarine deposits and shaly intervals with soil horizons (Leckie et al., 1994), relfecting base-level changes.

The isopach map of the transgressive portion of the Mannville shows that linear basement features are important in controlling the distribution of the lower part of the unit (Fig. 13). The few gas pools in the Cantuar appear to be stratigraphic traps where narrow, probably valley-fill sandstones, are surrounded by finer sediment.

DISCUSSION AND CONCLUSIONS

The discovered, expected potential, and probable potential gas volumes for each of the 16 mature plays are listed in Table 17. The total gas resource for each

Table 17

Discovered and potential in-place gas volumes (10^6 m^3) for mature Mannville plays

	Discovered	Expected potential	Probable potential
Northwest Alberta/northeast British Columbia			
Spirit River	102 582	28 888	74 412
Bluesky	105 478	48 585	105 280
Gething/Dunlevy	140 681	22 151	23 240
Cadomin	45 691	100 010	110 770
Athabasca			
Grand Rapids/Clearwater	87 535	55 060	110 880
Wabiskaw	53 957	21 776	35 932
McMurray	45 450	13 413	18 383
Lloydminster			
Colony to Lloydminster	212 535	87 008	92 406
Cummings	5 216	2 160	3 766
Dina	11 102	13 283	16 627
Central Alberta			
Glauconite/Upper Mannville	315 572	91 411	115 640
Ostracod	38 084	16 677	31 446
Basal Quartz/Ellerslie	257 755	67 399	74 819
Southern Alberta			
Upper Mannville/Glauconite	38 642	30 312	41 192
Ostracod/Lower Mannville	30 508	12 005	21 863
Alberta and Saskatchewan			
Detrital	11 432	33 563	37 151
Total	1 502 221 (53.1 TCF)	643 701 (22.7 TCF)	913 807 (32.3 TCF)

mature play is the sum of the potential (either at the expected or probable level) and discovered volumes. The expected potential has a lower uncertainty than the probable potential, because it is constrained by the range of individual discovered pool sizes, pool ranks, and geological play definition. The probable potential is derived by conditioning the play resource distribution on the sum of all discovered pool sizes for that play (Fig. 8) and is used to provide an upper limit to the estimated potential resource.

1. For this assessment the Mannville Group of the Western Canada Sedimentary Basin was divided areally and stratigraphically into 17 play types. These 17 play types were defined on a very broad and regional basis because of the large number of pools and the geological and economic complexities associated with the pool database of the Mannville Group. Therefore each of these 17 plays probably could be subdivided into more than one play type.

2. The Mannville Group contains 1 504 655 x 10^6 m^3 discovered gas-in-place (Tables 18, 19), which accounts for 23.6 per cent of the total discovered gas resources in the Western Canada Sedimentary Basin (Fig. 1). Based on the results of this study, the expected potential (undiscovered) gas resources of the Mannville Group are estimated to be 957 491 x 10^6 m^3 of gas-in-place, which represents 14.5 per cent of the total expected potential (undiscovered) gas resources of the Western Canada Sedimentary Basin (Fig. 87).

3. The discovered, expected, and probable potential for all the mature Mannville plays in the six different exploration regions are listed in Table 20. Central Alberta has the highest discovered gas resources, and northwest Alberta and British Columbia has the highest expected and probable potential resources.

4. The mature plays in the Mannville Group are ranked according to discovered in-place gas volume, expected and probable potential in-place gas volume and by largest undiscovered pool size in Tables 21 to 24. The plays with the largest discovered in-place gas volume are in the central Alberta and northwest Alberta and northeast British Columbia plays. The northwest Alberta/ northeast British Columbia–Cadomin play is

Table 18

Discovered resources for immature Mannville plays (in-place gas volume in 10^6 m^3)

	Discovered	No. of pools
Saskatchewan–Cantuar	2434	4

Table 19

Total gas resources of the Mannville Group (in-place gas volume in 10^6 m^3)

	Discovered	Expected potential	Probable potential
Mature plays	1 502 221	643 701	913 807
Immature and conceptual plays	2 434	313 790	1 101 100
Total	1 504 655 (53.1 TCF)	957 491 (33.8 TCF)	2 014 907 (71.2 TCF)

Table 20

Discovered, expected potential and probable potential for the mature plays in the six exploration areas (in-place gas volume in 10^6 m^3)

	Discovered	Expected potential	Probable potential
Northwest Alberta/northeast British Columbia	394 432	199 634	313 702
Athabasca	186 942	90 249	165 195
Lloydminister	228 853	102 451	112 905
Central Alberta	611 412	175 487	221 905
Southern Alberta	69 151	42 317	63 055
Alberta and Saskatchewan	11 432	33 563	37 151

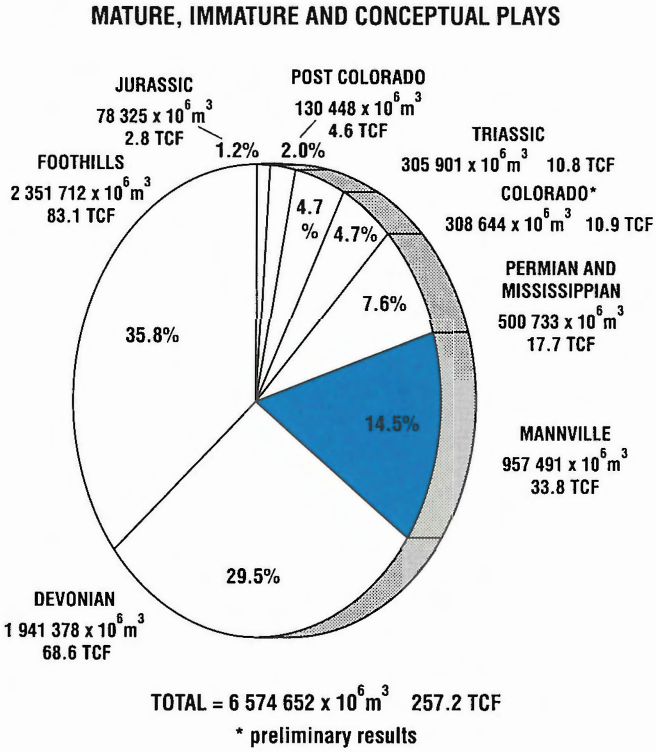


Figure 87. *Expected potential gas resources, Western Canada Sedimentary Basin.*

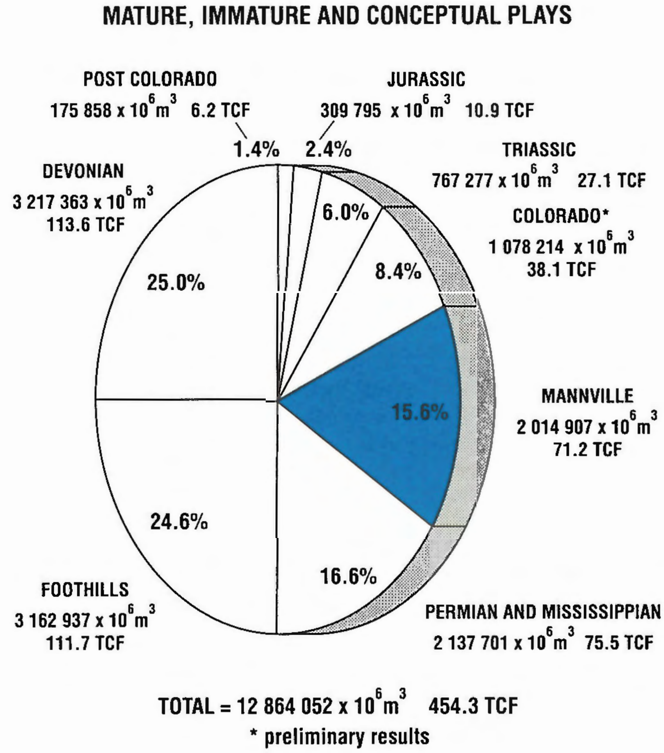


Figure 88. *Probable potential gas resources, Western Canada Sedimentary Basin.*

estimated to have the highest expected potential gas resources (Table 22) and also the largest undiscovered pool size (Table 24). The Lloydminster–Colony to Lloydminster play has the third highest expected potential. Future discoveries in this play will probably result from the extrapolation of productive trends in Alberta into Saskatchewan. As illustrated in the Lloydminster play maps, (Figs. 48, 51, 54) there is a marked decrease in the number of gas pools at the Alberta/Saskatchewan border and there is no geological control associated with this trend.

5. The total expected potential for the 16 mature plays is estimated to be 643 701 x 10^6 m^3 gas-in-place (Table 17) and 313 790 x 10^6 m^3 of gas-in-place for the immature and conceptual plays (Table 19). The total expected potential for the Mannville Group is 957 491 x 10^6 m^3 of gas-in-place and the probable potential is 2 014 907 x 10^6 m^3 of gas-in-place (Table 19; Figs. 87, 88). Comparing these estimates to the discovered gas resources of the Mannville Group (1 504 655 x 10^6 m^3), 39 to 57 per cent of the total gas resources in the Mannville Group remains to be discovered. Only 26 per cent of the undiscovered resources is estimated to be present in mature plays. The remaining 13 to 31 per cent is present in immature and conceptual plays

6. The pool database used in the Mannville Gas Assessment is as of December 1990. Therefore it represents only a partial dataset for the 1990 discoveries because of the period of confidentiality. As of December 1993, an additional 69 666 x 10^6 m^3 gas-in-place has been discovered in the Mannville Group. Given that this repesents an increase of 4 per cent of the total Mannville gas resources in 3 years, the expected potential value of 957 491 x 10^6 m^3 gas-in-place (39 per cent increase in total gas resources) could be conservative.

Table 21

Mature plays ranked according to discovered in-place gas volume

Rank	Play	In-place volume (10^6 m^3)
1	Central Alberta–Glauconite/Upper Mannville	315 572
2	Central Alberta–Basal Quartz/Ellerslie	257 755
3	Lloydminster–Colony to Lloydminster	212 535
4	Northwest Alberta/northeast British Columbia–Gething/Dunlevy	140 681
5	Northwest Alberta/northeast British Columbia–Bluesky	105 478
6	Northwest Alberta/northeast British Columbia–Spirit River	102 582
7	Athabasca–Grand Rapids/Clearwater	87 535
8	Athabasca–Wabiskaw	53 957
9	Northwest Alberta/northeast British Columbia–Cadomin	45 691
10	Athabasca–McMurray	45 450
11	Central Alberta–Ostracod	38 084
12	Southern Alberta–Upper Mannville/Glauconite	38 642
13	Southern Alberta–Ostracod/Lower Mannville	30 508
14	Alberta and Saskatchewan–Detrital	11 432
15	Lloydminster–Dina	11 102
16	Lloydminster–Cummings	5 216
	Total	1 502 221 (53.1 TCF)

Table 22

Mature plays ranked according to expected potential in-place gas volume

Rank	Play	In-place volume (10^6 m^3)
1	Northwest Alberta/northeast British Columbia–Cadomin	100 010
2	Central Alberta–Glauconite/Upper Mannville	91 411
3	Lloydminster–Colony to Lloydminster	87 008
4	Central Alberta–Basal Quartz/Ellerslie	67 399
5	Athabasca–Grand Rapids/Clearwater	55 060
6	Northwest Alberta/northeast British Columbia–Bluesky	48 585
7	Alberta and Saskatchewan–Detrital	33 563
8	Southern Alberta–Upper Mannville/Glauconite	30 312
9	Northwest Alberta/northeast British Columbia–Spirit River	28 888
10	Northwest Alberta/northeast British Columbia–Gething/Dunlevy	22 151
11	Athabasca–Wabiskaw	21 776
12	Central Alberta–Ostracod	16 677
13	Athabasca–McMurray	13 413
14	Lloydminster–Dina	13 283
15	Southern Alberta–Ostracod/Lower Mannville	12 005
16	Lloydminster–Cummings	2 160
	Total	643 701 (22.7 TCF)

Table 23

Mature plays ranked according to probable potential in-place gas volume

Rank	Play	In-place volume (10^6 m^3)
1	Central Alberta–Glauconite/Upper Mannville	115 640
2	Athabasca–Grand Rapids/Clearwater	110 880
3	Northwest Alberta/northeast British Columbia–Cadomin	110 770
4	Northwest Alberta/northeast British Columbia–Bluesky	105 280
5	Lloydminster–Colony to Lloydminster	92 406
6	Central Alberta–Basal Quartz/Ellerslie	74 819
7	Northwest Alberta/northeast British Columbia–Spirit River	74 412
8	Southern Alberta–Upper Mannville/Glauconite	41 192
9	Alberta and Saskatchewan–Detrital	37 151
10	Athabasca–Wabiskaw	35 932
11	Central Alberta–Ostracod	31 446
12	Northwest Alberta/northeast British Columbia–Gething/Dunlevy	23 240
13	Southern Alberta–Ostracod/Lower Mannville	21 863
14	Athabasca–McMurray	18 383
15	Lloydminster–Dina	16 627
16	Lloydminster–Cummings	3 766
	Total	913 807 (32.3 TCF)

Table 24

Mature plays ranked in order of largest undiscovered pool size

Rank	Play	In-place volume (10^6 m^3)	Area
1	Northwest Alberta/northeast British Columbia–Cadomin	10 856	2.5 Twp.
2	Northwest Alberta/northeast British Columbia–Bluesky	4 694	2.2 Twp.
3	Northwest Alberta/northeast British Columbia–Spirit River	1 824	23 Sect.
4	Central Alberta–Ostracod	1 346	6 Sect.
5	Athabasca–Wabiskaw	1 346	32 Sect.
6	Central Alberta–Glauconite/Upper Mannville	1 127	16 Sect.
7	Central Alberta–Basal Quartz/Ellerslie	1 112	14 Sect.
8	Southern Alberta–Ostracod/Lower Mannville	1 046	7.8 Sect.
9	Alberta and Saskatchewan–Detrital	966	10 Sect.
10	Southern Alberta–Upper Mannville/Glauconite	901	6 Sect.
11	Lloydminster–Dina	840	11 Sect.
12	Northwest Alberta/northeast British Columbia–Gething/Dunlevy	635	5 Sect.
13	Athabasca–Grand Rapids/Clearwater	712	15 Sect.
14	Athabasca–McMurray	408	13 Sect.
15	Lloydminster–Colony to Lloydminster	255	3.5 Sect.
16	Lloydminster–Cummings	245	3 Sect.

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