Chapter 1 – Introduction to the Geological Atlas of the Western Canada Sedimentary Basin


Introduction

Purposes

This Atlas is designed primarily as a reference volume. Only a few users will have the endurance to read and digest the whole tome, from cover to cover. Most will want to concentrate on certain chapters or certain specific geological relations, as illustrated in selected maps, cross sections or other diagrams. Yes, individual figures are designed to be largely self-explanatory, and yes, individual chapters are intended to be relatively self-contained. But there are myriad qualities of the Atlas that reflect larger concepts and more pervasive design criteria than first glance will readily allow users to grasp. The principal purposes of this first chapter are to introduce users to the geological parameters that predominate the overall scope and structure of the book, the standards and protocols that apply throughout, and the negligent assumptions and constraints – in short, to provide a guide to the use of the Atlas as a reference work.


Stratigraphic Divisions

Of the 35 chapters in the Atlas, 19 deal with designated stratigraphic divisions or "silts", some encompassing whole geological periods and others concentrating on smaller but exceptionally important stratigraphic units (e.g., Cretaceous Cardium Formation). The bounding surfaces between divisions are set at major unconformities or at stratigraphically significant and widespread marker horizons. Definitions of the bounding surfaces are discussed in each chapter and are catalogued in detail in the electronic Atlas database.

As is true for the rest of the Atlas, each division chapter is dominated by illustrations. Some are discretionary in nature but most are standard. The standard illustrations include index map, correlation chart, reference logs, structure map on the top bounding surface, gross division isopach map, sub-basin isopach and lithofacies maps, and a series of regional or "master" cross sections along transect lines common to all chapters. The assumptions and constraints that apply to these standard figures are discussed under the heading Atlas Illustrations.

The text of each division chapter is intended to establish the basic geological context of the subject stratigraphic slice, to guide the user in interpreting the illustrations, and to furnish references to the essential literature. Standard headings and contents in division chapters are discussed under Atlas Text.

Themes

Sixteen Atlas chapters are devoted to generic or thematic material. They are designed to address aspects of the general geological, geophysical, geochemical and geometrical character of the strata. Some deal with discrete tectonic domains (Cordillera, Williston Basin/Sweetgrass Arch, Peace River Arch), some with basin processes such as hydrocarbons generation and heat flow, some with very specific topics like stress distribution and sequence stratigraphic applications, and others with very broad and general overview themes such as Phanerozoic basin development and the paleogeographic evolution of the cratonic platform and of the foreland basin. Two chapters, 1 and 35, address the use and scope of the Atlas itself and of the Atlas database. These deal specifically with the economically important resources of the basin – oil and gas, coal, and minerals.

The theme chapters are much less structured than the stratigraphic division chapters, and their illustrations are much more discretionary. They are in effect review papers that summarize the state of knowledge and provide reference access to the open literature.

Contents and Organization

As one might expect, the sequencing of chapters in the Atlas is basically chronological, beginning with the crystalline basement and progressing through the Proterozoic and Phanerozoic bedrock successions to the Quaternary sediments that mantles the present-day ground surface. Theme chapters are interspersed with the division chapters.

In order to establish the context of the chapter-by-chapter discussions that follow, it is necessary to review briefly the overall geologic history of Western Canada, for it is the preserved vestiges of that history that the Atlas is intended to depict.

Geological History of Western Canada

On the most elementary level, the undeformed portion of the Western Canada Sedimentary Basin...
Figure 1.1 Geological map of the Western Canada Sedimentary Basin, showing the regionally and stratigraphically generalized distribution of Phanerozoic rocks in the Interior Plains (commonly mantled by Quaternary cover) and the schematic distribution of major Phanerozoic and Phanerozoic tectonic wedges in the Canadian Rocky Mountains.
the Omineca Belt, must have supplied the vast majority of the detritus that filled the foreland basin (or at least its sandstone component, for there are simply not sufficient sand sources in the carbonate-dominated Paleozoic rocks that were also caught up in the deformation).

Chapter 6, dealing as it does with selectively preserved remnants of a much broader succession, is dominated by cross sections rather than maps. It should be emphasized that the upper boundary of the stratigraphic division is placed not at the top of the Proterozoic but at the unconformity atop the Lower Cambrian Gog Group and its correlatives, for there are clearly stronger affinities between the underlying quartzy Proterozoic strata and the quartzy Gog Group than there are between the Gog and the overlying carbonate and shale strata of the Middle Cambrian.

Cratonic Platform

Chapter 7 through 16 illustrate and describe the cratonic platform succession beneath the Interior Plains, and equivalent deformed rock belts.

Paleogeographic Evolution - Cambrian to Triassic (Kent, this volume, Chapter 7) Serving as an overview of the eight chapters that follow, Chapter 7 describes, and more importantly depicts, the paleogeographic history of the Western Canada cratonic platform through the whole of the Paleozoic and into the Triassic. Featured are 12 full-page paleogeographic maps at selected intervals, showing the distribution of facies belts not only for the preserved successions but also for the postulated former extent of those same successions. The accompanying text is intended to provide a descriptive overview of the history of the cratonic platform, and its evolution, expressed in the changing location and shape of the southern margin of the cratonic continent, and its interactions with the paleocean and the surrounding regions. The maps are designed for reference to some degree, for simplicity of presentation, but it is that very simplicity that allows them to provide the desired overview and at the same time complement the commonly more detailed but less accessible geographic maps that appear in subsequent chapters. For readers unfamiliar with basic sedimentation and preservation patterns in the Paleozoic and Mesozoic it may be helpful to consider the following comments on the layout of the volume.

Middle Cambrian - Lower Ordovician (Blind et al., this volume, Chapter 8). In the undeformed part of the Western Canada Sedimentary Basin, the Cambrian succession rests with profound unconformity on crystalline rocks of the Precambrian basement, and on the west over deformed Lower Cambrian strata of the Gog Group. Fine-grained clastic facies in the southern Interior Plains give way westward to extremely thick carbonate successions that are spectacularly exposed in the Main Ranges of the Canadian Rocky Mountains. Farther west, there is an "outer detrital facies" dominated by the thick pelitic rocks of the Channellor Group and equivalents. If the Middle and Upper Cambrian succession is to be stratigraphers and structural geologists working in the Rockies, it is also, reciprocally, something of an enigma to workers in the deep subsurface of the southern Plains and the Hay River Embayment of northeastern British Columbia. Lacking in commercial petroleum production, the Cambrian succession in Western Canada must be considered one of the most notably under-explored successions extant.

For mapping purposes, this stratigraphic division is partitioned into two subdivisions - a Middle Cambrian succession to the PinkUNS, and an overlying Upper Cambrian (and lowermost Ordovician) succession, truncated at a major unconformity in the Interior Plains.

Middle Ordovician - Silurian (Norford et al., this volume, Chapter 9). Ordovician and Silurian rocks in the Western Canada Sedimentary Basin are the basis of distinct realms. The Middle Ordovician basin succession is confined geographically to southeastern Alberta, southern Saskatchewan and southern Manitoba, and stratigraphically from the uppermost Middle Ordovician to the lowermost Upper Silurian. Both the top and the base are major unconformities.

Chapter 13 emphasizes the Walmanian Group of the Peace River Arch, where the principal oil fields are located, and the Cordovaess Formation. The distribution belt of the Cordovaess is related to the Melville Island and possibly the Tuktoyaktuk, partly because of the presence of carbonate rocks.

Carboniferous (Richards et al., this volume, Chapter 14) Like Chapter 12, the Carboniferous chapter is markedly oxidized, partly because of the increased thickness of the Cordovaess Formation and the preservation of carbonate rocks in the Western Canada Sedimentary Basin and partly because of the economic importance of Carboniferous petroleum resources.

Included at the bottom of the division are uppermost Devonian rocks of the basal Eosawak and Bakkun formations. The top surface of the division is a profound regional unconformity, truncating Upper Carboniferous strata in the Rocky Mountains and progressively bevelling Lower Carboniferous strata toward the east in the Interior Plains. These principal assemblages - Bann, Rundle, and Mountain Vistas - are recognized accord by sequence boundaries. Derivation of these maps and related cross sections involved extensive reconstructions of both the Lodgepole-Raft and the Matmors-Stoddart strata. Complicating the stratigraphic analysis of the uppermost rocks of this division is the so-called Kaituna member in the Peace River Embayment, the fact that during the course of the compilation new stratigraphic data were obtained indicating that much of what was formally mapped as part of the Permian Bellay Formation is actually of Late Carboniferous age (see discussion in Chapters 14 and 15).

Schematic models and cross sections illustrate the carbonate ramp and slope environments that characterized Carboniferous sedimentation. Special discussion is devoted to the influence of Arktik tektites on Carboniferous stratigraphy and structure.

Permian (Henderson et al., this volume, Chapter 15) Permian strata of the Western Canada Sedimentary Basin are a continuous sequence of the Interior Plains to the Peace River Embayment and the Liard Basin of northeastern British Columbia, and in the Cordillera to the south. In the Peace River Embayment and the Liard Basin, the strata are uniformly dominated by non-marine distal deltaic successions, recorded in the delta front facies of the Fortymile, Stoney, and Disney groups, which are exposed by the Mackenzie Delta and the Liard River. The strata are dominated by an extensive continental basin, the Peace River Basin, which is subdivided into the Peace River Arch and the Peace River Embayment. The "event" markers that are used to partition the strata into chronostratigraphically significant "intervals" (subdivisions), and which serve as a basis for regional Atlas mapping, are from the base up: Beavertail Lake, Cooking Lake, Smoky Lake, Denervan, Lower Isson, Upper Isson, Nioki and Blue Ridge. The interval from the top of the Blue Ridge to the base of the Melville Formation and equivalents (i.e., units such as the Trout River, Gramina, and Crowfoot), formally designated as part of the Winterburn Group, is mapped in the Atlas as part of the Walmanian Group (Chapter 13).

Chapter 12 features extensive discussion and presentation of Leduc reefs and carbonate platform reservoirs of the Grosment and Nioki formations.

Devonian Walmans/Waumawan Group (Halbertsma, this volume, Chapter 13) Devonian strata of the Walmans/Waumawan Group equivalents are widespread throughout the Interior Plains, as are correlatives of the Palisor Formation and equivalents in the mountains. These rocks are afforded full chapter treatment because of their own inherent economic significance, particularly for natural gas, and because they constitute the last of the major Devonian carbonate platform cycles. The Devonian-Carboniferous boundary occurs in the black shales of the overlying Eosawak Formation and equivalents, just above the top of the Walmans.

Forland Basin

Chapter 17 through 24 deal with the rocks of the forland basin, in their present belt and belt outside the Interior Plains.

Paleogeographic Evolution - Jurassic to Tertiary (Smith, this volume, Chapter 17) In a manner similar to the Chapter 7 overview of the cratonic platform, Chapter 17 describes and depicts the paleogeographic history of the Western Canada Forland Basins. Chapter 18 provides a detailed summary of the stratigraphy and paleogeographic history of the Minto Group. Chapter 19 discusses the paleogeographic history of the Dogrib and 100 Mile Basins. Chapter 20 examines the paleogeographic history of the Frontier and 100 Mile Basins. Chapter 21 provides a detailed summary of the stratigraphy and paleogeographic history of the Dogrib and 100 Mile Basins.
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are 14 full-page paleogeographic maps at selected intervals, keyed to inset correlation charts. The maps provide a synthesis of deposition in the foreland basin, and the text sets out the essential features of the geological history. There is also discussion of both the strengths and the limitations of such paleogeographic mapping.

Jurassic and Lowermost Cretaceous (Poultun et al., this volume, Chapter 18) Strata in this chapter range from Lower Jurassic Heitanger to Lower Cretaceous Valanginian, bracketed top and bottom by major unconformities. There are two distinct but linked depositional and preservation domains — the Fernie-Minnen succession in the Cordillera and the west-central Alberta subsurface, and the Upper Watrous-Elk/Vanguard-Success succession in the southern Interior Plains. A total of seven internal stratigraphic subdivisions are recognized and mapped. The uppermost subdivision, including Kootenay, Naknek, Deville and Suicide strata, constitutes the sedimentary record of the first major pulse of Cordilleran tectonism. The clastics-dominated succession is western derived and dominantly non-marine in character. The first essentially significant coal deposits of the Western Canada Sedimentary Basin at this stratigraphic level.

Cretaceous Mannville Group (Hayes et al., this volume, Chapter 19) The second major wedge of Cordilleran-derived clastics shed into the foreland basin comprises the Balmoral/Mannville groups and their correlatives. The wedge extends throughout the length and breadth of the Western Canada Sedimentary Basin. Rivalled only by the sub-Ek Poistun unconformity beneath the Devonian, the sub-Mannville unconformity is perhaps the most profound in the entire succession. Mannville rocks overlie Jurassic strata in the west and south, and strata as old as Ordovician in the north and east (Fig. 19.3). Mannville Group strata host over 10 percent of the basin’s conventional oil reserves and over 25 percent of its natural gas resources. They provide access to the prodigious bitumen resources of the oil sands deposits.

For mapping purposes, the Mannville is partitioned into three subdivisions — the Cudmore/Cat Bank succession (proximal to the Cordillera front) and Lower and Upper Mannville successions (both extremely widespread). Chapter 19 features a number of sub-regional maps and sections illustrating stratigraphic controls on hydrocarbon accumulation.

Cretaceous Colorado/Alberta Group (Leckie et al., this volume, Chapter 23) Post-Mannville strata of Late Albian to Early Campanian age are dominated by marine shales encasing generally thin but extensive sandstones. The sandstones that punctuate the succession of are of enormous economic importance as petroleum reservoirs because they are generally the most productive of these units — the Viking, Duvernay and Cardium formations. Chapter 20 sets the stratigraphic context for the whole of the Colorado/Alberta Group, from the top of the Mannville to the Milk River shoulder, and deals specifically with the many other sandstone units that are either productive or prospective.

Chapter 20 features extensive depiction and discussion of depositional styles and stratigraphic trapping mechanisms in selected Colorado sandstone bodies.

Cretaceous Viking Formation (Reinson et al., this volume, Chapter 21) The Viking Formation and its equivalents contain very important gas and oil reserves in many parts of the Western Canadia Sedimentary Basin, particularly in southern Alberta and southwestern Saskatchewan. Traps are stratigraphic in nature and subtle in expression. Detailed stratigraphy and facies analysis provide the keys to their discovery and development.

Chapter 21 places particular emphasis on examples of how stratigraphic architecture and facies relations control the localization of hydrocarbon pools.

Figure 13 Schematic representation of Atlas stratigraphic strata in the Jurassic to Paleocene foreland basin succession. The Jurassic, Mannville, Colorado/Alberta, and pre-Mannville strata are each shown as separate stratigraphic units, with additional details of the principal sandstone units in the Colorado Group, Viking, Duvernay and Cardium.

Cretaceous Duvernay Formation (Bhattacharya, this volume, Chapter 22) The second of the prominent sandstone units in the Colorado Group is the Cretaceous Duvernay Formation. This formation is a generally thin sandstone and conglomerate unit, exposed in the Bow Basin and south-central Alberta. It is a prolific producer of oil (over 10 percent of the reserve) and it hosts the superbirgan Pembina oil field, the largest in the country.

Chapter 23 features a special "electrofacies" map and a number of special-purpose local maps and sections illustrating the geological character of prominent fields.

Uppermost Cretaceous and Tertiary (Dawson et al., this volume, Chapter 24) Above the Milk River marker lies a very thick succession of Cretaceous and Tertiary strata that represent the third and final major sedimentary wedge of the Western Canada Foreland Basin, the culmination of the Laramide Orogeny. Preserved only in part, because of deep post-Paleocene erosion, this succession lies in the up-hole portion of most of the oil and gas wells in the region, and control for Atlas mapping is extensively supplemented by stratigraphic data from shallow coal exploration wells. Over 70 percent of the measured coal reserves of interest in the basin stem from this succession (Fig. 23.18). Included in the strata dealt with in this chapter are post-orogenic remnants of Fleece formation fluvial sediments deposited in terraced drainage systems, in a regime that is otherwise characterized by net erosion and sediment bypass.

Sequence Stratigraphy

Chapter 25 (Bhattacharya and Pozmeniuch, this volume) is devoted to the application of sequence stratigraphy in the Alberta Foreland Basin successions. Examples are drawn from strata illustrated in the previous six chapters, and models are discussed for interpreting the interplay between eustasy, tectonics and sediment supply in an actively subsiding foreland setting (as opposed to the passive foreland basin setting in which the concepts of sequence stratigraphy were originally founded).

It is interesting to note here that, just as the original atlas (McCraesan and Glaisier, 1964) was published during the formative years of plate tectonic theory (and it consequently contains only tangential reference to plate tectonics), so this Atlas was compiled during the formative years of sequence stratigraphic analysis. Much of the stratigraphy remains to be deciphered and analyzed in sequence stratigraphic terms.

Quaternary-Recent

The final division chapter (Fenton et al., this volume, Chapter 26) is devoted to the Quaternary record. Processes that culminated the post-orogenic erosional denudation of the bedrock are described, as are the deposits left behind by the retreating Pleistocene ice.

Featuring in this chapter are three key maps - topography on the bedrock surface, drift thickness and present-day topography. Sub-regional illustrations and accompanying text portray the facies complexity that characterizes the mostly unconsolidated Quaternary sediment.

Tectonic Domains

Having dealt with the Proterozoic to Quaternary record of the Western Canada Sedimentary Basin on a slice-by-slice basis, it is appropriate to devote a couple of chapters to discrete tectonic domains within the cratonic interior, domains that influenced and even controlled the sedimentary history of the Proterozoic. The combination of horizontal stratigraphic slices and facies and genetic realms may be viewed as a three-dimensional geological matrix of basin architecture.

Williston Basin and Sweetgrass Arch (Kent and Christopher, this volume, Chapter 27) This chapter constitutes an encompassed geological history of the Canadian portion of the Williston Basin in southern Saskatchewan and Manitoba and the Sweetgrass/Bow Island/North Battleford Arch complex on its western flank in southeastern Alberta, with extended reference to the stratigraphy and structure of both domains south of the Canada/U.S. border (49°N). The chapter brings into focus the profound influence of vertical tectonics (uplift and subsidence) in the deposition and preservation of Phanerozoic strata in the southern Interior Plains.

Peace River Arch (O’Connell, this volume, Chapter 28) It may be argued that the intra-cratonic depocenters, the Phanerozoic sedimentation in the Western Canada Sedimentary Basin, none is more important than the Peace River Arch. Its initial period of activity in the early Paleozoic and Devonian was followed by collapse in the Carboniferous and Permian, to form the Peace River Embayment depocenter of the Late Paleozoic and early Mesozoic. The presence of the arch/embayment can be detected in strata as high as Upper Cretaceous.

Featured in Chapter 28 are selected maps and cross sections illustrating faulting and sedimentation at representative intervals through the Phanerozoic.

Geotechnique

Having described and depicted the geological history of the Western Canada Sedimentary Basin, the Atlas scores on the map of processes that currently affect the basin — existing stress conditions and present-day patterns of heat distribution and heat flow. It is designed to reveal the current stress states at depth, and to record the effects of the processes that currently affect the basin — existing stress conditions and present-day patterns of heat distribution and heat flow. It is designed to reveal the current stress states at depth, and to record the effects of the processes that currently affect the basin — existing stress conditions and present-day patterns of heat distribution and heat flow. It is designed to reveal the current stress states at depth, and to record the effects of the processes that currently affect the basin — existing stress conditions and present-day patterns of heat distribution and heat flow. It is designed to reveal the current stress states at depth, and to record the effects of the processes that currently affect the basin — existing stress conditions and present-day patterns of heat distribution and heat flow. It is designed to reveal the current stress states at depth, and to record the effects of the processes that currently affect the basin — existing stress conditions and present-day patterns of heat distribution and heat flow. It is designed to reveal the current stress states at depth, and to record the effects of the processes that currently affect the basin — existing stress conditions and present-day patterns of heat distribution and heat flow.
Coal Resources (Smith et al., this volume, Chapter 33) Canada’s coal resource endowment is overwhelmingly dominated by deposits of the Western Canada Sedimentary Basin – thermal coal in the plains and metallurgical coal in the mountains. Coal measures in the basin are hosted in rocks as old as Jurassic and as young as early Tertiary.

Chapter 33 features a full-scale map of all of the defined coal fields in the basin, keyed to stratigraphic occurrence. Coal composition and rank parameters are illustrated in ternary diagrams of maceral groups and histograms of petrological reflectance classes. Maps of isomaturity for various coals and their hosts provide important information on the overall burial and exhumation history of the basin, which in turn influences interpretations of the nature and origin of petroleum.

Mineral Resources (Hamilton and Olson, this volume, Chapter 34) Both flinty and non-flinty mineral deposits in the Western Canada Sedimentary Basin are discussed in Chapter 34. The geological characteristics of each of more than 30 different minerals are described, in the context of a systematic classification scheme for producers, prospects, showings and anomalies.

Featured in Chapter 34 are two full-scale mineral maps, one for metallic deposits and occurrences and the other for industrial mineral deposits and occurrences. The maps are keyed to extensive data tables on the locations and characteristics of all known occurrences.

Automated Data Processing for the Atlas

The final chapter in the Atlas (Sheets and Mosipp, this volume, Chapter 35) describes the computer processing of voluminous amounts of Atlas stratigraphic and lithological data, the software developed for data testing and control point selection, the nature and derivation of the Atlas database, and aspects of data maintenance and map production. Atlas-specific techniques for data analysis are also outlined.

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Basic Atlas Standards

Stratigraphic Nomenclature

Virtually all of the stratigraphic nomenclature used in the Atlas conforms to generally accepted practice, including in a few instances some informal designations (e.g., "Base of Fish Scales"). In general, however, usage is per the Lexicon of Canadian Stratigraphy, Volume 4 Western Canada (Elass, 1990).

Indexing

The Index at the back of the Atlas is a matrix guide to standard illustrations. Users wishing to find, for example, Elk Point paleogeography maps, should simply refer to the intersection of the Elk Point row with the Paleogeography columns. Indexed illustrations are cited by both figure number and page number.

Colour Schemes and Symbols

Colour Schemes

The use of colour is one of the most standardized aspects of the Atlas. There are three distinct but complementary colour schemes.

1. The first scheme is designed to depict lithology (Fig. 1.4). In many ways it conforms to generally accepted practice – carbonates in blues, purple and lavenders, sandstones in yellows, etc. – although readers accustomed to orange silt or green salt, for example, may have some difficulty in adapting. In essence, the scheme is broadly spectral. Red is reserved for crystalline rocks. The orange-yellow-green part of the spectrum is given over to coarse-to-fine-grained silticlastics, with most shales shown in green although there is a gray alternative. Blues and purples are reserved for carbonate rocks, and pinks and tans for evaporites. Non-spectral intermediate colours are used for the designation of mixed lithologies (for example, grayish-blue for mixed clastics and carbonates).

2. The second colour scheme is designed to depict depositional environments and paleogeography (Fig. 1.5). Again, the scheme is basically spectral. Reds and purples are reserved for the highest and driest depositional settings, such as mountains, alluvium and sabkha (note the general congruence with conglomerates and evaporites of the lithology colour chart); greenes denote fluvial and swampy settings (with questionable congruence to fine-grained clastics, but with satisfying paleogeographic imagery). Sandy shoreline systems are in yellows, grading offshore to gray muds. Carbonate depositional systems are in blues, the shallowest in light tones and the deeper ones in darker tones (schematically imaging relative bathymetry).

The third and final colour scheme depicts age or stratigraphic division (Fig. 1.6). In part, the scheme recapitulates the previously published and widely referenced cross sections of Western Canada (Wright, 1984; see also Wright et al., this volume, Fig. 3.4). With some exceptions in the lower Paleozoic (orange for Cambrian, pink for Ordovician-Silurian), the scheme is again broadly spectral. The youngest rocks of the Tertiary and Mesozoic are in yellow and greens. Blues and purples are reserved for the Permian, Carboniferous and Devonian. Browns are invoked for the Proterozoic. This colour scheme is congruent to the other two because the Paleozoic to Triassic cratonic platform succession in Western Canada is dominated by marine carbonates (and shales), while the Jurassic-Cretaceous to Tertiary foreland basin succession is characterized by mixed non-marine and marine sandstones (and shales). Thus the blues/purples are appropriate for cratonic platform carbonates and the greens/yellows are appropriate for foreland basin clastics.

One final point on the use of these colour schemes is that practically all of the coloured Atlas illustrations have their own colour legends, with detailed written descriptions of precisely what the authors intend to depict in terms of lithology, environment or age. The colour schemes described above provide a general framework for the use of colour but in any one diagram or map or cross section the legend sets out the specifics.

Symbols Patterns and symbols are used in many Atlas illustrations. These generally conform to common usage. Symbols for lithologies and sedimentary structures are in most cases based on CanStrat protocols (Canadian Stratigraphic Service, 1989). Map symbols (e.g., reefs, muds, bars, etc.) generally conform to the standards of the Geological Survey of Canada (Cameron et al., 1989).
Atlas Illustrations

Three quarters of the Atlas volume is made up of figures. What follows is a selection of the character and limitations of Atlas figures.

Atlas Maps

There are over 230 maps in the Atlas. Most are at Atlas standard scales: 15 000 000 (Western Canada spanning the full Atlas page); 1:100 000 (strictly mapped); and 1:20 000 (column maps). There are also numerous local and sub-regional maps at smaller scales (the so-called "zoom-in" maps).

A majority of the Atlas maps were compiled directly by chapter teams. These include index maps, paleogeography maps, specialized regional maps (e.g., potential field maps, tectonic maps) and local maps (showing the facial relations that underpin the regional stratigraphic architecture). Many of these maps are schematic or quasi-schematic. Some are highly explicit (e.g., showing relations between real structures and individual Devonian oil pools).

The most extensively assembled Atlas maps are those that depict structure, thickness and lithofacies, constructed for all of the principal stratigraphic divisions and subdivisions in the Phanerozoic. There are 90 such maps, almost all at 1:5 000 000 scale. They were compiled jointly by the chapter authors and the two Atlas compilers, who carried out the digital data analysis and mapping at project headquarters in Edmonton. All of these "principal" Atlas maps contain postings of control points, affording users insight into how rigorously the contours and domains are spatially constrained.

Readers are referred to Chapter 35 for information on the basic elements of Atlas data processing techniques and the custom computer programs that were developed to integrate and analyze the subsurface data and compile the "principal" maps.

Base Map

The Atlas base map (see Fig. 1.7) is a Lambert Conformal Conic projection on Lambert’s conformal area, with parallels 52° 15' and 58° 45'N. Political geography and surface hydrography are more generalized than published survey maps, with the largest and most prominent cities, rivers and lakes retained. The township/range grid, posted every 10 townships for rudimentary location reference, is standard for Western Canada (for details of the grid structure see the clear plastic insert to this Atlas).

Phanerozoic Edge "The Eastern zero-edge of Phanerozoic cover", the western and southwestern limit of the exposed Canadian Shield, is digitized from the Geological Map of Canada (Douglas, 1968), with slight local modification, mostly in the Dominion City Channel region southeast of Winnipeg.

Disturbed Belt Fronts

Disturbed Belt Fronts are the western and southwestern limits of unaltered rocks in the Western Canada Sedimentary Basin. They are depicted on the geological section analysis designed to detect, on successive east-west transects, the easternmost evidence of significant stratigraphic or tectonic force. They are correlated with the eastern limits of bituminous rocks, as shown by transmission from the Horseshoe Island Trough, and they are marked by a profound change in the type of sediments deposited throughout the Mesozoic and Cenozoic.

It is evident that all of these methods are in part utilized in the regional mapping of the Canadian Shield, as defined by the change from Precambrian to sedimentary rocks. The Canadian Shield is characterized by a general increase in the thickness of sedimentary rocks, particularly in the eastern part of the country. The thicknesses increase from the west to the east, and there is a general decrease in the age of the rocks from the west to the east. The Canadian Shield is divided into several provinces, each with its own characteristic geology.

Contour Resolution

Atlas contours honour the control-point data to the maximum degree possible. For most maps, from zero to five percent of the control z-values are defined by the contours. Some data points are violated simply because it would be neither geographically pleasing nor conceptually justified to introduce highly localized contour convolutions that obscure or distract from regional contour patterns or, worse, imply a level of mapping precision that is simply not warranted at the scale of the Atlas. If the control data indicate a significantly more pronounced surface roughness, and more than five percent of the control values are violated, contours are referred to in the map legend as "generalized".

It should be emphasized that control points so violated are not expunged from the electronic Atlas database, for they are considered by authors and compilers to be accurate and therefore of value to researchers, particularly for sub-regional or local mapping applications.

Vector Resolution

Just as the contours are subject to some generalization, so too are the geographic boundaries. In particular, the boundaries shown on the printed maps. Subcrop outlines, for instance, were drawn by authors on the basis of computer-generated immediate maps with location postings in both "real" thickness values (finite isopach) and "null" thickness values (isopach interval apparently absent). Given that neighbouring well points are spaced from 2 km to 5 km apart, it is obvious why such geographic vectors must be considered generalized.
In cases of generally concordant surfaces, colour patterns in the postglacial are normally somewhat diffuse, for they reflect how the use of stratigraphic names varies taxonomically from one sub-
region to another. For example, in the Grand Rapids Formation (group vs. formation vs. member) or as a function of (historically
rooted) designations of type or reference sections. Thus the top
bounding surface of the Marenven division (Fig. 18.23), for exam-
ple, is generally designated over wider areas as Marenven Group or
Blawood Group, sub-regionally as the Spirit River Formation or
the Grand Rapids Formation, or locally as the Colony Member.
Other examples of this kind of nomenclature may be seen in
Figures 13.35 (Wahamuni) and 21.3 (Viking).
It should be noted that some of these so-called “concordant” sur-
faces are actually unconformities or discordominalities, but they lack
significant angularity in their contact relations with underlying strata.

Oil and Gas Fields
Most of the significant oil and gas fields in each Atlas division are
represented on either the structure contour map or the division
isopach map of the corresponding chapter. Field outlines are digit-
ized polygons based on pool data supplied by the relevant provin-
cial agencies, compiled for the Geological Survey of Canada by
P. Hay in cooperation with DigiBase Information Services, final-
ized for the Atlas maps by D. McPhee. Details of the conduct and
results of the compilation are contained in Hay (this volume, Chap-
ter 32).
Atlas maps show most but not all of the significant hydrocarbon
fields (the single-well and small multi-well pools are simply too
small to illustrate at the Atlas scale). Tables accompanying the
subject maps give resource, reserve and production statistics, to-
gether with pool size distributions and short narrative descriptions
of reservoir occurrences. All such tables were compiled by Hay.
Although practically all fields are shown, only the largest fields, to
a maximum of ten per map, are labelled, using a scheme of num-
bered cross-references. In this way, the maps are not inordinately
cluttered by field labels. Oil fields are in green, gas fields in red.
The compilation by Hay adheres very closely to the Atlas designa-
tions of stratigraphic subdivisions; there is a single population of
oil and gas fields for each Atlas division. The exceptions to this
rule lie in the Carboniferous (Chapter 14), where the compilation of
fields is subdivided into the upper, middle and lower Pennsylvanian;
and the Mannville (Chapter 19), where the oil and gas fields, tabulated and depicted in separate Lower Mannville and Upper
Mannville subdivisions. Specialized treatment also is afforded the
hydrocarbon fields in the Colorado Group (Chapter 20), where
hydrocarbon accumulations in the most prominent sandstone
units are depicted separately. Cretaceous oil sands deposits are
depicted on the Mannville isopach map (Fig. 19.4).
Most hydrocarbon traps in the Western Canada Sedimentary Basin
are stratigraphic in nature. For this and other reasons, preference is
given to showing oil and gas fields on the relevant division isopach
map. Exceptions occur where the division isopach map also serves
as the basis for depiction of lithofacies (lithofacies being normally
depicted on subdivision isopachs). In these cases, the map colour
patterns are simply too complex to allow for appropriate resolu-
tion of the hydrocarbon fields. Thus, in the Vermilion (Fig. 13.35),
the Pernian (Fig. 15.13) and two of the three prominent Colorado
sub-basins, and in the Roche Dupes (Fig. 22.7), hydrocarbon
fields are shown on the corresponding structure contour maps.

Lithofacies Maps
Most of the 48 Atlas subdivision isopach maps are accompanied by
colour-coded isopach maps, which illustrate the locations of
lithofacies bands depicted on the subdivision isopach maps. The
lithofacies maps are based on the compilation of Atlas lithofacies
bands carried out by the Geological Survey of Canada, and
Canadian Stratigraphic Service Ltd. through Home Oil Corpora-
tion. The exception is the Woodbend-Winterburn subdivision maps,
where the compiler team furnished independently derived lithofacies
portrayals.

INTRODUCTION

Similar resolution lee-way applies to outcrop limits and, to a lesser
extent, to oil and gas field outlines. Much broader resolution lee-
way must be allowed for vectors that are inherently transitional or
highly non-concordant in nature (e.g., facies boundaries, shelf edges,
arch axes, etc.).

Survey Grid Overlay
It is thus with some trepidation that a clear plastic insert of the
Western Canada survey grid supplied with this Atlas is included.
It is provided to allow users a means of accurately determining map
locations, but the potential for abuse is obvious and intrinsic.
There should be absolutely no implication that any map line
intersecting any given township square can be held to any
greater resolution than 10 km or more, and in many cases the resolution
is considerably worse. Atlas contours and vectors are intended to
illuminate regional trends and patterns, not local detail.

Contouring Protocols for “Structures”
In the Interior Plateaus to the east and northeast of the Cordilleran front, the Western Canadian Sedimentary Basin is essentially a free of reef and feldspars (see Wright et al., this volume, Chapter 3). The most important exceptions to this general rule occur in the region of the Peace River Arch (particularly the Fort St. John Graben complex; see Fig. 14.5) and near the margins of the Lizard Basin in northeastern
British Columbia, along the Bowie Lake Fault (see Figs. 3.2 and 3.3,
Chapter 1).

Normal fault symbology, with contours terminated against the
fault line, is used for the most pronounced faults, but in many
instances, faulting is portrayed by systematically deflected contour
patterns (see for example the Mattson isopach, Fig. 14.35; or the
Permian index map, Fig. 15.1).

Structure-Paleogeography - Nomenclature Maps
Structure Contours Each chapter team was responsible for ensur-
ing the integrity of data controlling the top bounding surface of its
division, commonly in consultation with the team(s) for the super-
incident(s). A structure contour map of that top surface appears in
every division chapter. There are 18 such structure contour maps in the
Atlas. Because the monocline dip of most such Atlas surface
features is comparatively pronounced, the contour interval is gener-
ally set at 100 m or 200 m.

Structure contours in subcrop zones do not extend beyond the
zero-edge of the subject interval, but their positioning at the zero-
edge is carefully matched to the equivalent structure contour in the
subcrop zone of the subjacent division. For example, the 400 m
contour for the Mannville Subdivision of the Upper Mannville, extends on into the subcrop area of the adjacent Pembina
Subdivision of the Lower Mannville. This reflects Pembina zero-edge to the 400 m contour of the Carboniferous
structure map (Fig. 14.8), and so on. The sub-Mannville unconfor-
mity structure map (Fig. 19.3) thus synthesizes all the subcrop parts of the divisions that are truncated beneath the Mannville.

Paleogeography - Nomenclature Each structure contour map shows
either subcrop paleogeography, or if it is an angular unconfor-
mity, or applicable stratigraphic nomenclature, if the surface is
industry or concordant. Subcrop structure maps are used to

Colour coding of the lithofacies domains generally conforms to
the Atlas lithology/lithofacies standards (Fig. 13.1), with quite a
colour hybrids introduced for mixed lithologies. For example, the
subdivision isopach map of the Wabamun sub-basin contains
mixed dolomites and evaporites in pinkish purples. Various
browns and reds are introduced where the lithological mixing is
so pronounced as to blur into other colours.

On any given lithofacies map, details of the portrayed lithofacies
are set out in an accompanying title block legend, which contains
descriptions not only of basic lithologies but also significant
petrological characteristics (colour, grain size, sorting, etc.); accessory constituents, and diagenetic components such as
cements, as well as limited palaeontological information (bry fossils and
gastropod shells). These accessory components are usually absent
in carbonate rocks (porosity, permeability). There is also some indication of the
degree and type of interbedding and, where appropriate, the vertical
variability of lithological constituents (e.g., “increasingly towards
top”).

Statistical characterization of lithofacies is contained in the insert
table on each map. For each facies domain is a percentage breakdown
of constituent lithologies, with bracketed indication of the
standard deviations. Where the percentage contribution of a
given constituent (e.g., conglomerates) is highly variable in the
subject domain, the standard deviation is relatively high. Com-
paratively low standard deviations indicate generally pervasive
representation of that constituent over the subject domain. Readers
are referred to Shenon and Mossop (this volume, Chapter 35) for
details on Atlas lithofacies processing.

The Canadas Lithofacies table is of course based on analysis of well
cuttings, and therefore is subject to all of the inherent potential
pittfalls and limitations (cavings contamination, constraints on the
recovery of fossils, etc.). A number of interdependencies
relates to lithofacies characterization in very thin zones (near
subcrop zero-edges) where percentage data become erratic (de-
pending on just what lithology is fortuitously preserved in the
zone of converging unconformities). This latter difficulty is com-
monly circumvented in Atlas lithofacies maps by labelling rim
zones simply as “variable lithology in thinner zones”.

The Lithofacies information does not readily distinguish between
inherent (depositional) lithology and secondary (diagenetic) com-
itments. For example, in white beds, with thin reddish or
celery beds, users are cautioned that entries such as Chert may reflect either beaded chert or pervasive amorphous silica cement. Even
terms like Limestone (Calcareous Component) or Anhydrite may reflect diagenetic rather than depositional constituents in the rock (calcite
cement or late secondary anhydrite).

Notwithstanding all the limitations and cautions, it is nonetheless
important to point out that experience gained in Atlas data pro-
cessing shows the Canadas Lithofacies list to be remarkably sound in
terms of data integrity and consistency. Atlas-defined lithofacies
domains complement and reflect very closely the subsurface expe-
rience of authors, whose facies studies (though commonly in
comparison with those of many other teams) are based on detailed
and geophysical log suites. In the writers’ experience, inferences drawn
from Lithofacies processing are reliable, certainly the best available
for extended stratigraphic sections where cores are generally lack-

Wells with Canadas control of the subject interval are indicated by
triangles and therefore are the least reliable for detailed interval
stratigraphic control only). Users will note that the density of
Canadas control is at least an order of magnitude greater in Alberta
and B.C. than in the Prairies, reflecting the higher density of
wells. Inferences drawn from the lithofacies maps should be tempered
accordingly.
Figure 1.7 Index map of Atlas subsurface control, showing the designated “Atlas control wells” and the lines of regional “master” cross sections.
There are two reasons for applying standard cross section scales. The first reason is that sections, typically located in the Cordillera, need to fit the vertical image dimension of the Atlas pages (~35 cm) and the longest sections need to be confined in length to two Atlas pages (about 100 cm, on facing pages, the section broken at the gutter), thus allowing spans of up to 2500 km. The second is more conceptual and designed to facilitate appropriate comparisons from division to division. At standard scales, thin or areally confined successions (such as the Permian of the Peace River Embayment) are difficult to portray and more widespread successions (such as the Carboniferous, Figs. 14.24 and 14.25) on the basis of visual impact alone, without the necessity of mental or manual conversions. Just as the principal Atlas maps are standardized at 1:500 000, so the Atlas regional cross section are standardized at 1:6000 and 1:2 500 000, to facilli- tate comparison. Scale Differences Figure 1.7 shows the transect lines for the six so-called "master cross sections" – longitudinal section A-A', and were labelled horizontal (Figs. 14.24 and 14.25) on the basis of visual impact alone, although the section lines do not perfectly fit the division scale. A standard section line is one that is drawn on the basis of the dominant depositional or facies transitions. In a few chapters (e.g., Ek P. Group, Chapter 10), discretional regional sections dominate to the near exclusion of dominant depositional or facies transitions. In a few chapters (e.g., Ek P. Group, Chapter 10), discretional regional sections dominate to the near exclusion of dominant depositional or facies transitions. In a few chapters (e.g., Ek P. Group, Chapter 10), discretional regional sections dominate to the near exclusion of dominant depositional or facies transitions. In a few chapters (e.g., Ek P. Group, Chapter 10), discretional regional sections dominate to the near exclusion of dominant depositional or facies transitions. In a few chapters (e.g., Ek P. Group, Chapter 10), discretional regional sections dominate to the near exclusion of dominant depositional or facies transitions. In a few chapters (e.g., Ek P. Group, Chapter 10), discretional regional sections dominate to the near exclusion of dominant depositional or facies transitions. In a few chapters (e.g., Ek P. Group, Chapter 10), discretional regional sections dominate to the near exclusion of dominant depositional or facies transitions. In a few chapters (e.g., Ek P. Group, Chapter 10), discretional regional sections dominate to the near exclusion of dominant depositional or facies transitions. In a few chapters (e.g., Ek P. Group, Chapter 10), discretional regional sections dominate to the near exclusion of dominant depositional or facies transitions. In a few chapters (e.g., Ek P. Group, Chapter 10), discretional regional sections dominate to the near exclusion of dominant depositional or facies transitions.
Chapter 20, where stress magnitude and orientation data are necessary to support the user's understanding of the associated maps.

Atlas Text
The foregoing deals with the three quarters of the Atlas given over to illustrations. What follows are brief descriptions of the standards that apply to the quarter of the Atlas that consists of text.

Text Content and Flow
Many but not all division chapters adhere to a pre-determined general outline, the idea being that similar content and flow in successive chapters permits users to become accustomed to where to find certain types of information. The following headings replicate the guidelines issued to authors for the content and flow of their manuscripts.

Introduction - overview of the rocks with which the chapter deals, including age, general stratigraphic/lithological character, general geographic distribution and thickness, relations to overlying/ununderlying slices, economic significance, and other earmark characteristics. Any constraints or limitations in data or treatment also are introduced.

Previous Work - narrative introduction to the key source literature on the subject strata, emphasizing prominent review papers and syntheses. This is not intended as a summary of how our knowledge of these rocks has accumulated over time. Rather, it is a guide to where the reader can achieve entry into the next important modern literature.

Geological Framework - capsule summary of the tectonic history and explanation of the geological features shown on the index map (e.g., tectonic domains, paleophysographic features).

Stratigraphic Nomenclature - explanation of the correlation chart, with any necessary discussion of terminological peculiarities, adopted practice/usage, and constraints on chronostratigraphic and biostratigraphic inference.

Stratigraphic History - summary of the overall depositional history, including stratigraphic architecture, general environments of deposition, and notable facies trends, commonly referenced to schematic sections or other schematic illustrations.

Regional Cross Sections - explanation of the salient stratigraphic features illustrated in both the master cross sections and the discretionary regional sections.

Reference Logs - discussion of the notable characteristics of each of the reference log suites.

Structure - explanation of the principle features of and constraints on the division structure map, with reference to depicted subcrop paleostratigraphy or stratigraphic nomenclature.

Further Reading
References in individual chapters provide access to most if not all of the important modern literature on the regional stratigraphy of the Western Canada Sedimentary Basin. Recommended additional reading on the nature and origin of the basin includes: the original Atlas (McCrosky and Glaser, 1964), most of the contents of which remain as valid today as when they were published; Bickett (1989), a case history of the nature and origin of the Western Canada Sedimentary Basin Macquarrie and Leclerc, 1992, a book on foreland basins and fold belts, three quarters of which is devoted to the foreland basin of Western Canada; Stott and Atkison (1993), the Decade of North American Geology volume on the cratonic cover of Western Canada; and Caldwell and Kaufman (in press), a book on the Mesozoic Western Interior Basin.

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