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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 predicate the overall scope and structure of the book, the standards and protocols that apply throughout, and the manifest assumptions and constraints – in short, to provide a guide to the use of the Atlas as a reference work.

Readers interested in a larger perspective on the overall purpose and history of the Atlas project are referred to the foreleaf pages, which set out basic project tenets and acknowledge the scores of individuals and institutions who participated, and to a series of published project reports (Mossop, 1986, 1988a, b, 1989, 1990, 1991; Mossop and Shetsen, 1987, 1988, 1989, 1990, 1991, 1992, 1993). A project summary paper is in preparation (Mossop, Shetsen, Madunicky and Dixon).

Stratigraphic Divisions

Of the 35 chapters in the Atlas, 19 deal with designated stratigraphic divisions or "slices", some encompassing whole geological periods (e.g., Triassic), others concentrating on smaller but economically important stratigraphic units (e.g., Cretaceous Cardium Formation). The bounding surfaces between divisions are set either 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, subdivision 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 reader in understanding and interpreting the illustrations, and to furnish references to the essential literature. Standard headings and contents in division chapters are discussed under Atlas Text.

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Themes

Sixteen Atlas chapters are devoted to generic or thematic material. They are designed to address aspects of the general geological, geophysical, geochemical and geotechnical character of the strata. Some deal with discrete tectonic domains (Cordillera, Williston Basin/Sweetgrass Arch, Peace River Arch), some with basin processes such as hydrocarbon 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. Three 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 referenced 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 mantle 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 geological 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 beneath the Interior Plains can be viewed as a simple wedge of Phanerozoic strata above Precambrian crystalline basement. The wedge tapers from a maximum thickness of about 6000 m in the axis of the Alberta Syncline (just east of the foothills front) to a zero-edge in the northeast along the Canadian Shield (see Fig. 3.2). The differentially eroded upper surface of the bedrock exposes basin strata as old as Ordovician and as young as Paleocene. The simplified geological map of Western Canada shown in Figure 1.1 represents the most basic template upon which early geologists began deciphering the nature and origin of the sedimentary wedge.

On a slightly more conceptually advanced level, the Western Canada Sedimentary Basin can be divided into two distinct parts, reflecting sedimentation in two profoundly different tectonic settings. The Paleozoic to Jurassic platformal succession, dominated by carbonate rocks, was deposited on the stable craton adjacent to the ancient (dominantly passive) margin of North America. The overlying mid-Jurassic to Paleocene foreland basin succession, dominated by clastic rocks, formed during active margin orogenic evolution of the Canadian Cordillera. Net erosion and sediment bypass have prevailed in the region since the Paleocene culmination of the Laramide Orogeny.

For most of the interval embraced by the platformal succession, patterns of marine inundation, sedimentation and erosion were strongly influenced by epeirogenic movements on various intracratonic arches, which episodically differentiated the region into a complex array of sub-basins and uplifts. An isopach map of the cratonic platform succession is shown in Figure 3.3.

To the west, in what is now the deformed belt, the cratonic platform succession gives way to a very thick wedge of sedimentary strata deposited on the ancient continental terrace. This wedge includes at its base a remarkable succession of Middle and Upper Proterozoic sedimentary rocks, the remnants of which are preserved only in slivered Cordilleran assemblages. Figure 1.2 depicts, in a highly schematic way, how rocks of the continental platform and terrace are partitioned for treatment in ten Atlas division chapters.

Beginning in the mid-Jurassic, as North America began to drift westward with the opening of the Atlantic, the western margin of the continent was subjected to at least two major episodes of compressional tectonism, as a result of collision with large oceanic terranes that accreted to the continent along its western margin. As a consequence of these collisions, sedimentary rocks deposited outboard of the ancient margin were compressed and displaced eastward over the continental margin. In turn, platformal cover rocks were thrusted and folded to form the Canadian Rocky Mountains and the Rocky Mountain Foothills. Emplacement of the imbricate thrust slices, progressively from west to east, produced thickening of the crust and downwarp of the foreland, forming an eastward-migrating foredeep that trapped clastic detritus shed from the developing mountains. The foreland basin wedge is characterized by upward-coarsening progradational cycles capped by extensive non-marine deposits. An isopach map of the foreland basin sedimentary wedge is shown in Figure 3.9. Figure 1.3 schematically illustrates how the foreland basin succession is partitioned for Atlas treatment.

Atlas Chapters

The following chapter-by-chapter descriptions are intended to provide users with a condensed overview of Atlas content and sequencing. Unless otherwise noted, division chapters can be taken as containing all or most of the standard Atlas illustrations, as outlined above under Stratigraphic Divisions and as described subsequently under Atlas Illustrations.

Basin Framework and Early History

Cordilleran Tectonics and Basin Evolution (Price, *this volume*, Chapter 2) The tectonic and stratigraphic history of the Western Canada Sedimentary Basin is inextricably linked to the origin and evolution of the Canadian Cordillera. The Canadian Rocky Mountains, the easternmost realms of the Cordillera, constitute an integral part of the basin. As a consequence of the compressional tectonics that formed the mountains, much of the ancient continental terrace wedge was destroyed through uplift and erosion, as were significant parts of the western cratonic platform succession. The rising mountains also supplied the vast majority of the sediment that filled the foreland basin. Columbian and Laramide tectonics had profound influences on foredeep sedimentation patterns.

Chapter 2 deals with both the large-scale plate tectonic history of Cordilleran development and the smaller-scale deformational history of the Rocky Mountain Thrust and Fold Belt. Balanced and restored structural cross sections through the Rockies are contained in both Chapter 2 and Chapter 3.

Basin Structure and Architecture (Wright et al., *this volume*, Chapter 3) Just as Chapter 2 provides an overview of the tectono-stratigraphic history of the deformed part of the Western Canada Sedimentary Basin, so Chapter 3 synthesizes the tectono-stratigraphic history of the (largely) undeformed part of the basin beneath the Interior Plains. Structures associated with epeirogenic fault movements and salt solution are major themes.

Chapter 3 contains, in addition to fundamental isopach maps, regional structure sections across the basin and along its axis (after Wright, 1984), plus illustrations of burial histories.

Potential Fields and Basement Structure (Ross et al., *this volume*, Chapter 4) If Chapters 2 and 3 encompass the most fundamental geological characteristics of the Western Canada Sedimentary Basin, Chapter 4 illustrates its most basic geophysical expression. The gravity and aeromagnetic maps contained in Chapter 4 cover practically the whole of the base map area, including large portions of the exposed Canadian Shield in the northeast and practically the whole of the British Columbia Cordillera in the southwest. Particular emphasis is placed on interpretation of the potential fields in the Interior Plains, beneath the undeformed parts of the basin, and on implications for deciphering basement tectonic domains.

Chapter 4 discusses deep crustal structure and the influence of basement tectonics on sedimentation and diagenesis patterns in the overlying Phanerozoic rocks.

Precambrian Basement (Burwash et al., *this volume*, Chapter 5) Direct knowledge of the basement beneath the Western Canada Sedimentary Basin is based on the hundreds of boreholes that penetrate deep enough to afford basement core samples. The chapter focuses on the composition of the basement rocks and their determined geochronology, and on associated implications for tectonic assembly.

Chapter 5 contains the Atlas structure contour map of the basement.

Proterozoic - Lower Cambrian (Hein and McMechan, *this volume*, Chapter 6) Absent from the consciousness of many workers in the Western Canada Sedimentary Basin is the fact that basin sedimentation did not begin with the widespread Middle and Upper Cambrian succession of the Interior Plains, but rather with the enormously thick Proterozoic succession that is preserved only in the mountains. These strata include the Middle Proterozoic Belt-Purcell Supergroup preserved in the southeastern Canadian Cordillera and the Muskwa Assemblage of northern British Columbia, and the Upper Proterozoic Windermere Supergroup. Unroofed during the early stages of Cordillera mountain-building, these Proterozoic clastic successions, together with crystalline rocks of

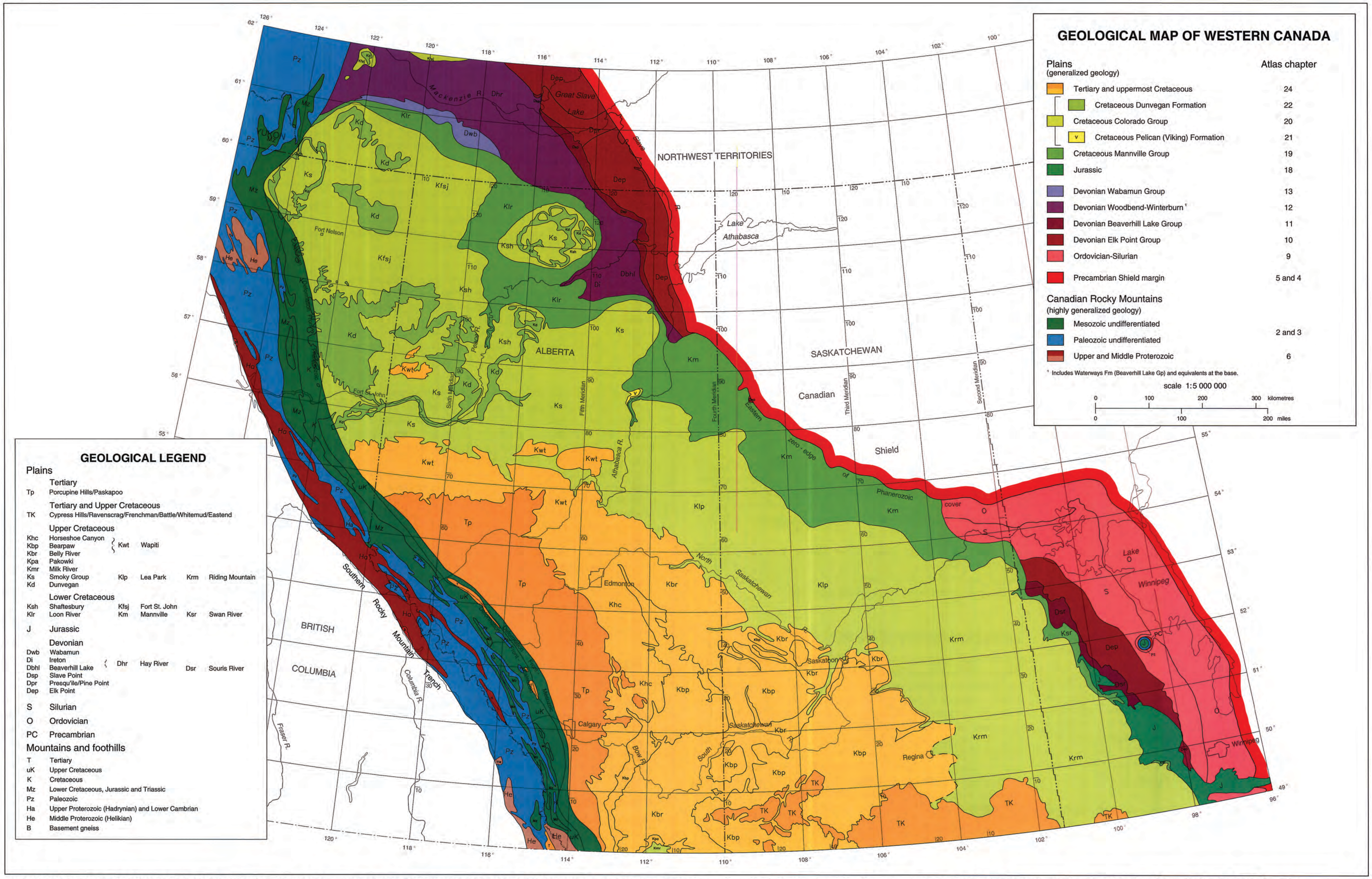

Figure 1.1 Geological map of the Western Canada Sedimentary Basin, showing the regionally and stratigraphically generalized distribution of Phanerozoic rocks in the Interior Plains (commonly mantled by Quaternary cover) and the schematic distribution of major Proterozoic and Phanerozoic tectonic wedges 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 quartzitic Proterozoic strata and the quartzitic Gog Group than there are between the Gog and the overlying carbonate and shale strata of the Middle Cambrian.

Cratonic Platform

Chapters 7 through 16 illustrate and describe the cratonic platform succession beneath the Interior Plains, and equivalent deformed rocks in the Canadian Rocky Mountains.

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 (subsequently eroded). The maps are generalized 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 paleogeographic maps that appear in subsequent chapters. For readers unfamiliar with basic sedimentation and preservation patterns in the cratonic platform, the Chapter 7 maps and accompanying descriptions serve as an essential introduction.

Middle Cambrian - Lower Ordovician (Slind 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 to the west on bevelled 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 Chancellor Group and equivalent. If the Middle and Upper Cambrian succession is a joy to 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 Pika Marker, 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 occur in two distinct realms. The Williston 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. The Williston Basin succession is partitioned into four distinct stratigraphic subdivisions and mapped accordingly.

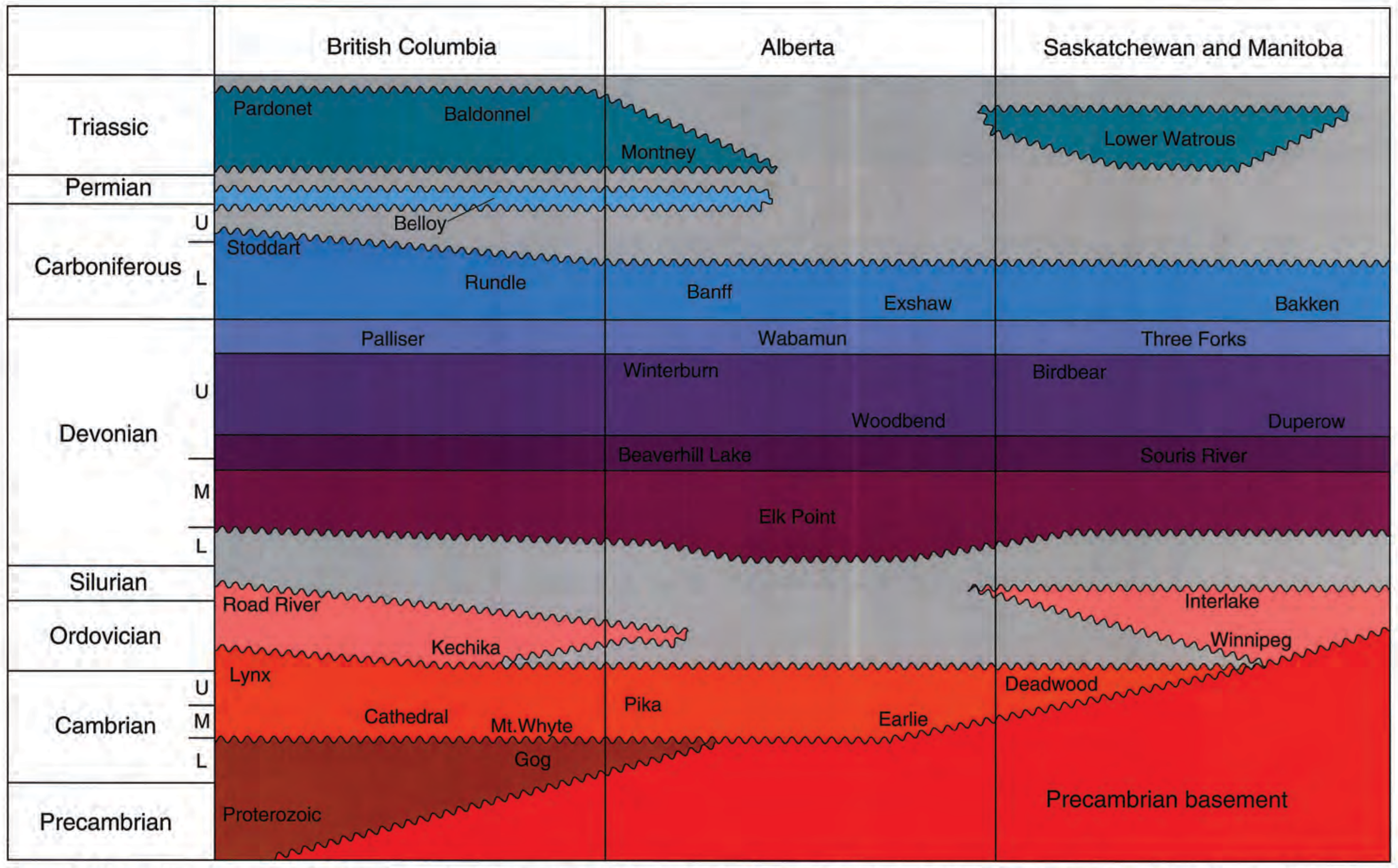

Figure 1.2 Schematic representation of Atlas stratigraphic divisions in the Proterozoic to Triassic cratonic platform and continental terrace succession. Each colour denotes a separate chapter.

The other major occurrence of Ordovician and Silurian strata is in the Canadian Rocky Mountains and the Mackenzie Platform in the Northwest Territories. Here the succession is much thicker than in the Interior Plains and generally more continuous. It embraces rocks from uppermost Lower Ordovician to Lower Devonian.

Devonian Elk Point Group (Meijer Drees, *this volume*, Chapter 10) The oldest of the economically important resources of the Western Canada Sedimentary Basin are the extensive potash deposits of the Lower to Middle Devonian Elk Point Group. Significant oil and gas resources occur in pinnacle reefs and other carbonate reservoirs in the Rainbow-Zama region of northern Alberta and around the Peace River Arch.

Devonian Beaverhill Lake Group (Oldale and Munday, *this volume*, Chapter 11) The established economic importance of these Givetian to Frasnian strata, pivoting around the Swan Hills petroleum reservoirs, warrants separate treatment for the Beaverhill Lake Group and its Manitoba Group equivalents. Stratigraphic partitioning distinguishes the Dawson Bay, Watt Mountain and Fort Vermilion at the base from the overlying "transgressive sequence" of the Slave Point and Swan Hills and the culminating "regressive sequence" of the Waterways and Souris River formations. This approach to stratigraphic definition and differentiation is better illustrated in paleogeographic maps than in standard subdivision isopach and lithofacies maps.

Devonian Woodbend - Winterburn Groups (Switzer et al., *this volume*, Chapter 12) This is really two chapters combined. Both the Frasnian Woodbend Group and the Frasnian to Famennian Winterburn Group, and equivalents, contain enormous petroleum resources, rivalled in the Western Canada Sedimentary Basin only by parts of the Cretaceous.

The Woodbend-Winterburn chapter team chose to pick and correlate anew virtually all of the markers in these successions, in all more than 7000 Atlas wells (this in contrast to the practice in other divisions where existing picks from provincial databases were taken as given unless selectively modified and optimized by author intervention). All of the new picks are integrated into the Atlas database.

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: Beaverhill Lake, Cooking Lake, Majeau Lake, Duvernay, Lower Ireton, Upper Ireton, Nisku and Blue Ridge. The interval from the top of the Blue Ridge to the base of the Stettler Formation and equivalents (i.e., units such as the Trout River, Graminia, and Crowfoot), formally designated as part of the Winterburn Group, is mapped in the Atlas as part of the Wabamun Group (Chapter 13).

Chapter 12 features extensive discussion and illustration of Leduc reefs and carbonate platform reservoirs of the Grosmont and Nisku formations.

Devonian Wabamun/Palliser Group (Halbertsma, *this volume*, Chapter 13) Famennian strata of the Wabamun Group and equivalents are widespread throughout the Interior Plains, as are correlative strata of the Palliser 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 Exshaw Formation and equivalents, just above the top of the Wabamun. Chapter 13 emphasizes the Wabamun Group of the Peace River Arch, where the principal oil fields are located, and the Crossfield Member gas reservoirs around Calgary.

Carboniferous (Richards et al., *this volume*, Chapter 14) Like Chapter 12, the Carboniferous chapter is markedly oversized, partly because of the great thickness and wide areal extent of Carboniferous rocks in the Western Canada Sedimentary Basin and partly because of the economic importance of Carboniferous petroleum reservoirs.

Included at the bottom of the division are uppermost Devonian rocks of the basal Exshaw and Bakken 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. Three principal assemblages – Banff, Rundle, and Mattson – are recognized and mapped accordingly as subdivisions. Derivation of these maps and related cross sections involved extensive recorrelation of both the Lodgepole-Banff and the Mattson-Stoddart strata. Complicating the stratigraphic analysis of the uppermost rocks of this division (the so-called Ksituan member in the Peace River Embayment) is the fact that during the course of the compilation new biostratigraphic data were obtained indicating that much of what was formally mapped as part of the Permian Belloy 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 Antler tectonics on Carboniferous stratigraphy and structure.

Permian (Henderson et al., *this volume*, Chapter 15) Permian strata of the Western Canada Sedimentary Basin are restricted in the Interior Plains to the Peace River Embayment and the Liard Basin of northeastern British Columbia, and in the Cordillera to the Ishbel/Prophet Trough. Sedimentation and preservation patterns were strongly influenced by syn- and post-depositional block faulting, particularly in the Peace River Embayment. Special discussion is focused on the petroleum-bearing Belloy Formation of the Peace River Embayment.

Triassic (Edwards et al., *this volume*, Chapter 16) Just as the Permian is bounded top and bottom by unconformities, so too is the Triassic succession, which is preserved roughly in the same areas. Triassic strata are clastics-dominated, derived from the craton to the east. Four subdivisions are recognized in the Peace River Embayment: Montney, Halfway-Doig, Charlie Lake, and Pardonet-Baldonnel. These strata already produce significant quantities of oil and gas and their future potential is considered high. A large area of evaporite rocks and redbeds in southern Saskatchewan and Manitoba, the Lower Watrous/Lower Amaranth formations, are now considered to be Triassic in age and are herein mapped as such.

Chapter 16 features detailed illustration and discussion of the difficult internal correlations, and elucidation of the geology and reservoir characteristics of representative fields.

Foreland Basin

Chapters 17 through 24 deal with the rocks of the foreland basin, in the disturbed belt and across 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 Foreland Basin. Featured 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 (Poulton et al., *this volume*, Chapter 18) Strata in this chapter range from Lower Jurassic Hettangian to Lower Cretaceous Valanginian, bracketed top and bottom by major unconformities. There are two distinct but linked depositional and preservational domains – the Fernie-Minnes succession in the Cordillera and the west-central Alberta subsurface, and the Upper Watrous-Ellis/Vanguard-Success succession in the southern Interior Plains. A total of seven internal stratigraphic subdivisions are recognized and mapped. The uppermost subdivision, including Kootenay, Nikanassin, Deville and Success 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 economically significant coal deposits of the Western Canada Sedimentary Basin occur 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 Blairmore/Mannville groups and their correlatives. The wedge extends throughout the length and breadth of the Western Canada Sedimentary Basin. Rivalled only by the sub-Elk Point 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 reserves, plus practically all of the prodigious bitumen resources of the oil sands deposits.

For mapping purposes, the Mannville is partitioned into three subdivisions – the Cadomin/Cut Bank succession (proximal to the Cordilleran 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 entrapment.

Cretaceous Colorado/Alberta Group (Leckie et al., *this volume*, Chapter 20) 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 are of enormous economic importance as petroleum reservoirs, and Chapters 21, 22 and 23 deal respectively with the most productive of these units – the Viking, Dunvegan and Cardium formations. Chapter 20 sets the stratigraphic context for the whole of the Colorado 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 Canada 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.

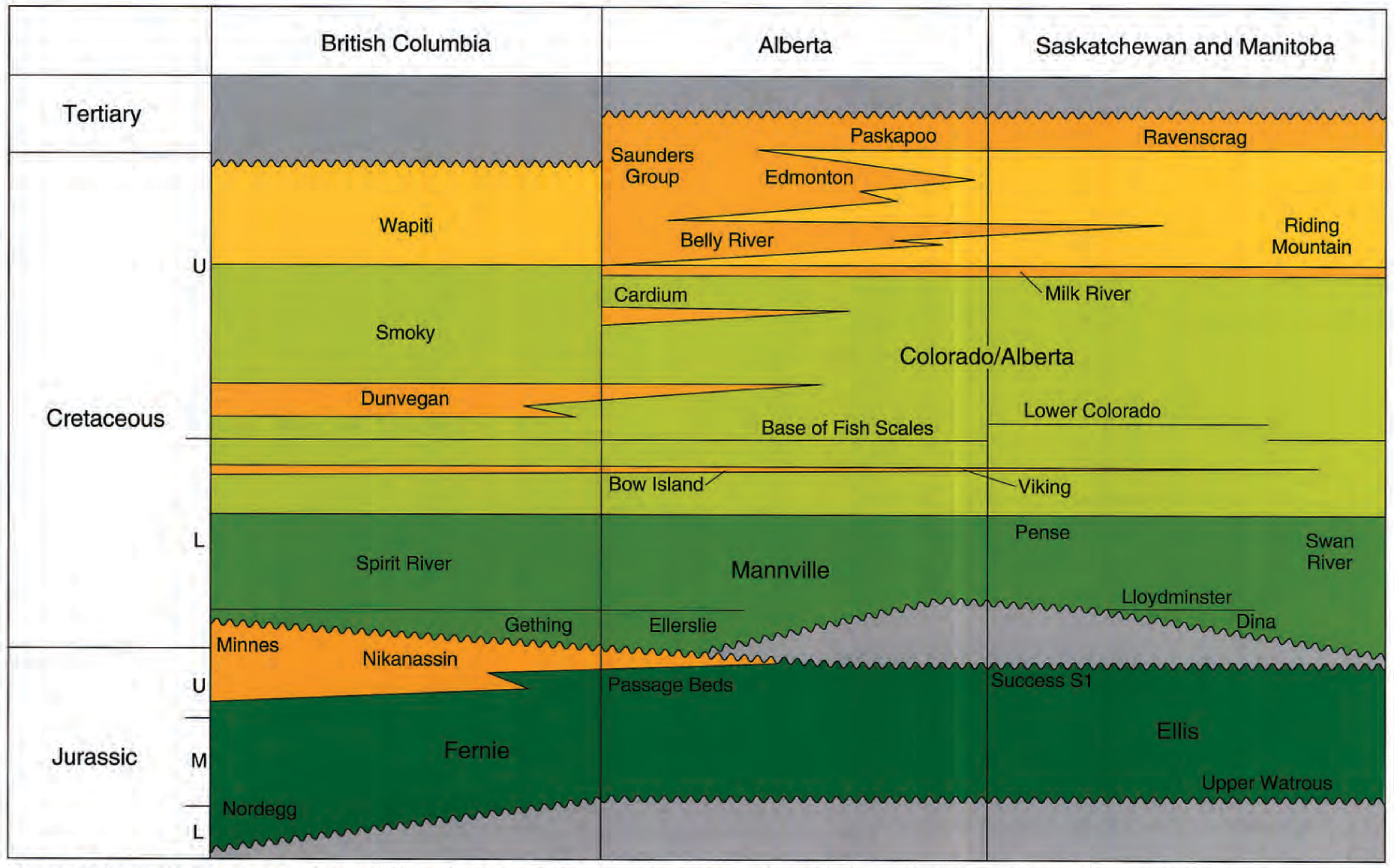

Figure 1.3 Schematic representation of Atlas stratigraphic divisions in the Jurassic to Paleocene foreland basin succession. The Jurassic, Mannville, Colorado/Alberta, and uppermost Cretaceous-Tertiary slices are each afforded separate-chapter treatment, with additional chapters devoted to the principal sandstone units in the Colorado Group - Viking, Dunvegan and Cardium.

Cretaceous Dunvegan Formation (Bhattacharya, *this volume*, Chapter 22) The second of the prominent sandstone units in the Colorado Group is the Cenomanian Dunvegan Formation of northeastern British Columbia and northwestern Alberta. This large delta complex is extensively exposed in the northwestern plains and foothills, and it extends into the subsurface northwest of Edmonton, where it produces oil and gas. Strata discussed in this chapter include the Dunvegan Formation itself and the overlying Doe Creek and Pouce Coupe sandstones.

Chapter 22 features detailed paleogeographic profiling of the evolution of the southeastern (productive) portion of the Dunvegan delta complex.

Cretaceous Cardium Formation (Krause et al., *this volume*, Chapter 23) The last of the Colorado Group sandstones singled out for separate-chapter treatment is the Turonian-Coniacian Cardium Formation. The Cardium is a generally thin sandstone and conglomerate unit, confined to the Bow Basin of western and southwestern Alberta. It is a prolific producer of oil (over 10 percent of the basin's reserves) and it hosts the supergiant 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 Campanian to Paleocene 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 immediate interest in the basin stem from this succession (Fig. 33.18). Included in the strata dealt with in this chapter are post-orogenic remnants of Eocene to Pliocene fluvial sediments deposited in terraced drainage systems, in a regime that otherwise is characterized by net erosion and sediment bypass.

Sequence Stratigraphy

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

It is interesting to note here that, just as the original atlas (McCrossan and Glaister, 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 basin 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.

Featured 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 sediments.

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 dictated sedimentation patterns during extended periods of the Phanerozoic. The combination of horizontal stratigraphic slices and vertical tectonic 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 encapsulated 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 can be argued that, of the intra-cratonic structural domains affecting Phanerozoic sedimentation in the Western Canada Sedimentary Basin, none is more important than the Peace River Arch. Its initial period of uplift in the early Paleozoic and Devonian was followed by collapse in the Carboniferous and Permian, to form the Peace River Embayment depocentre of the late Paleozoic and early Mesozoic. The influence 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 goes on to elucidate some of the processes that currently affect the basin – existing stress conditions and present-day patterns of heat distribution and heat flow. This volume does not address current conditions of formation fluid composition and flow.

In-situ Stress (Bell et al., *this volume*, Chapter 29) The state of stress in the subsurface has much to tell us about both present and past structural and geodynamic influences on the basin. In addition, understanding the stress regime has very important implications for invasive engineering (e.g., boreholes, induced fractures), which in turn affects enhanced petroleum recovery and mine development.

Chapter 29 sets out data on the present state of knowledge of stress in the Western Canada subsurface. Three regional-scale maps are featured - horizontal stress orientations in the Paleozoic rocks and the Mesozoic rocks, and overall stress trajectories. Stress magnitudes also are discussed.

Geothermal Regime (Bachu and Burwash, *this volume*, Chapter 30) Understanding the distribution of heat in the Western Canada Sedimentary Basin provides important insights into both modern and ancient processes of thermal alteration and fluid flow affecting both organic and inorganic constituents in the rock.

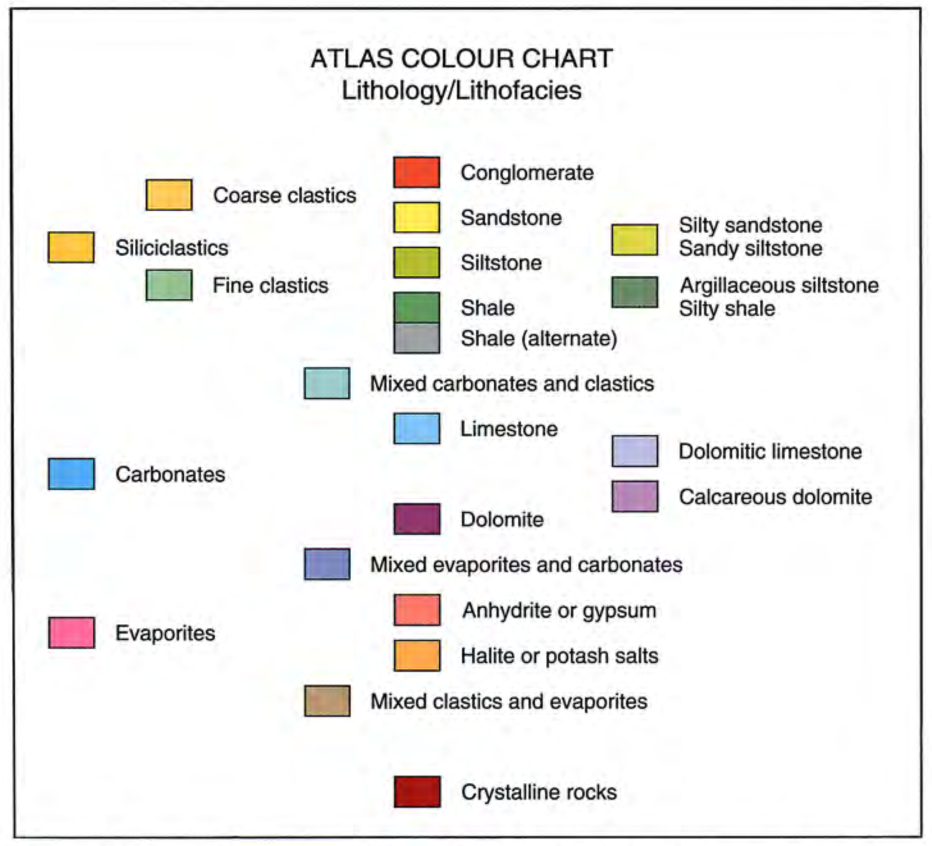

Figure 1.4 Atlas colour scheme for illustrations depicting lithology or lithofacies.

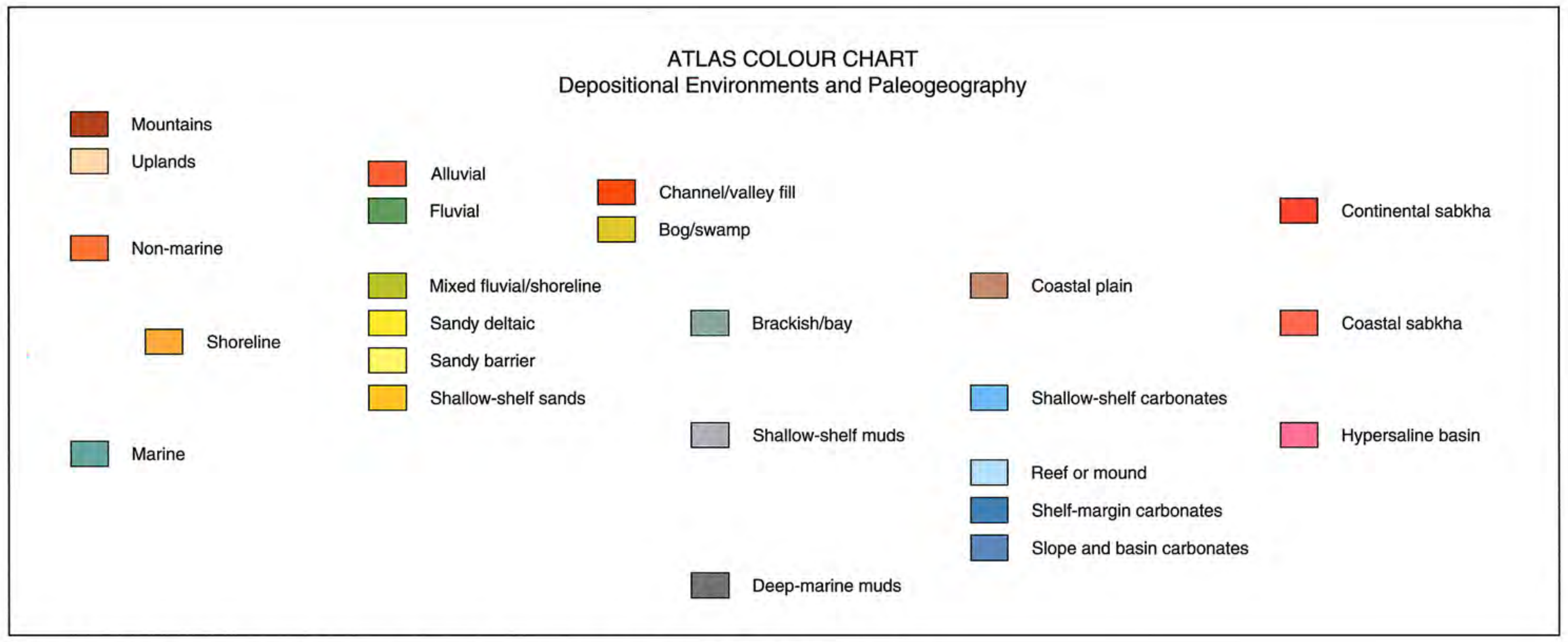

Figure 1.5 Atlas colour scheme for illustrations depicting depositional environments or paleogeography.

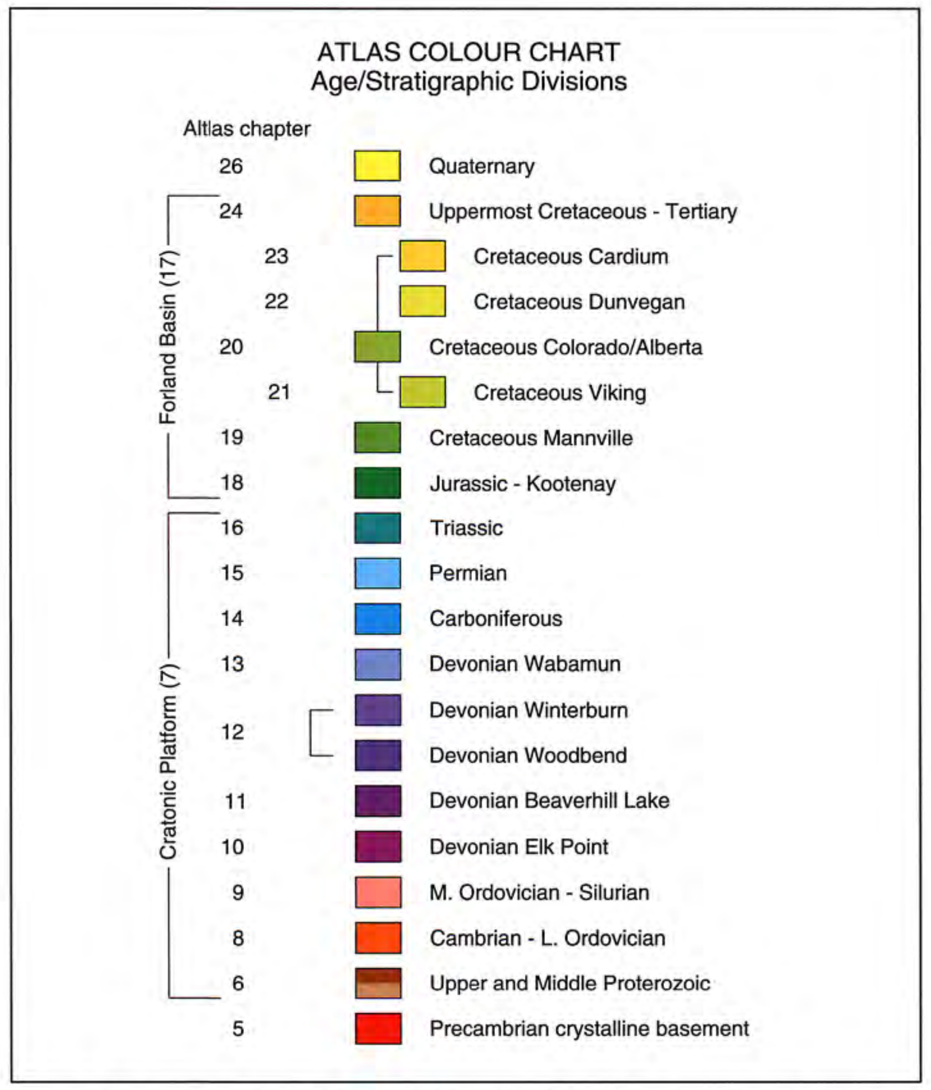

Figure 1.6 Colour codings for Atlas stratigraphic divisions, in accordance with age/superposition.

Four basin-wide maps are featured in Chapter 30 – heat generation at the Precambrian surface, temperature at the Precambrian surface, integral geothermal gradient, and basement heat flow.

Resources

Four Atlas chapters are devoted to the pivotally important earth resources contained in the Western Canada Sedimentary Basin – two to petroleum, one to coal and one to minerals.

Petroleum Generation and Migration (Creaney et al., *this volume*, Chapter 31) With the tremendous advances that have taken place in our collective understanding of source rocks, thermal maturation, expulsion, migration and entrapment, keyed by breakthroughs in organic petrology and organic geochemistry, it is appropriate that the Atlas devote a chapter to summarizing the state of knowledge about the processes controlling the generation and migration of petroleum in the Western Canada Sedimentary Basin. If one takes into account the overwhelmingly large resources of heavy oil and bitumen that are hosted in deposits updip from the conventional traps, there is no doubt that the Western Canada Sedimentary Basin is one of the most prolific petroleum-yielding basins in the world.

Chapter 31 illustrates the distribution of immature, mature and overmature source rocks for each of nine petroleum systems recognized in the basin – Ordovician, Devonian Keg River/Brightholme, Devonian Duvernay, Devonian Nisku, Devono-Carboniferous Exshaw-Bakken/Lodgepole, Triassic Doig, Jurassic Nordegg, Cretaceous Mannville, and Cretaceous Colorado Group petroleum systems – with paired graphs of associated geochemical characteristics. Expulsion and migration pathways and timing (dominantly Late Cretaceous) are discussed together with aspects of thermal and biological alteration processes acting on pooled petroleums.

Oil and Gas Resources (Hay, *this volume*, Chapter 32) Most of the effort devoted to compiling Atlas oil and gas field outlines, reservoir descriptions, and reserve and resource statistics is not evident in the Chapter 32 manuscript, because the compiled maps and data tables are not exhibited there. They are continued in the Atlas division chapters to which they relate. What is contained in Chapter 32 is a description of data sources and methodologies, together with consolidated information on reserves and production for all petroleum-bearing stratigraphic divisions in the basin.

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 host strata provide important information on the overall burial and exhumation history of the basin, which in turn influences interpretations of the nature and origin of petroleums.

Mineral Resources (Hamilton and Olson, *this volume*, Chapter 34) Both metallic and non-metallic mineral deposits in the Western Canada Sedimentary Basin are discussed in Chapter 34. The geological characteristics of each of more than 50 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 (Shetsen and Mossop, *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.

Atlas Principles and Protocols

Each of the 35 Atlas chapters is authored by a different team of geologists and, naturally, content and style vary from chapter to chapter. Nonetheless, a host of standard illustration elements and text formats apply to all chapters.

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 (Glass, 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 column. 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 features of the Atlas. There are three distinct but complementary colour schemes.

The first scheme is designed to depict lithology (Fig. 1.4). In many ways it conforms to generally accepted practice – carbonates in blues and purples, 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 siliciclastics, with most shales shown in green although there is a gray alternative. Blues and purples are reserved for carbonate rocks, 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).

The second colour scheme is designed to depict depositional environments and paleogeography (Fig. 1.5). Again, the scheme is basically spectral. Reds (pinks) and oranges are reserved for the highest and driest depositional settings, such as mountains, alluvium and sabkhas (note the general congruence with conglomerates and evaporites of the lithology colour chart). Greens 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 Atlas 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 yellows 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 Jura-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., faults, meltwater channels, 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 series of descriptions of the character and limitations of Atlas figures.

Atlas Maps

There are over 230 maps in the Atlas. Most are at Atlas standard scales: 1:5 000 000 (Western Canada spanning the full Atlas page); 1:10 000 000 (maps of two-column width); and 1:20 000 000 (one-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 facies 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 reef structures and individual Devonian oil pools).

The most exactingly 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, centred on 111°W longitude, with standard parallels 52° 15' and 58° 45'N. Political geography and surface hydrography are more generalized than published survey maps, with only 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, most notably in the Dominion City Channel region southeast of Winnipeg.

Disturbed Belt Fronts The western and southwestern limits of undeformed rocks of the Western Canada Sedimentary Basin, the eastern and northeastern limits of Cordilleran deformation, are in part generalized from published regional maps and in part derived from the results of Atlas data analysis designed to detect, on successive east-west transects, the easternmost evidence of significant deformation. The deformation fronts were finalized in consultation with R. McMechan and P. Fermor of Shell Canada Ltd. and M. McMechan of the Geological Survey of Canada.

North of about latitude 55°N, where the front of the disturbed belt is dominated more by folds than by faults, there is a single (and somewhat arbitrary) line defined for the edge of folding. It applies to all Phanerozoic rocks of the basin (Fig. 1.7). Farther south, two lines are defined. Both are generalized, because it is not possible at the Atlas scale to portray the complexly juxtaposed array of thrust sheets that characterize the fronts. The line labelled "Deformation Front – Mesozoic" (Fig. 1.7) more or less coincides with the triangle zone, the eastern limit of deformation in near-surface structures affecting the Jura-Cretaceous succession. In all Atlas contour maps of Mesozoic strata, this line represents the western and southwestern limit of automated gridding and contouring. The line labelled "Deformation Front – Paleozoic" (Fig. 1.7) marks the eastern and northeastern limit of thrusted Paleozoic strata, commonly at depth. This line is used on all Atlas maps of Paleozoic strata as the western and southwestern limit of automated gridding and contouring. All contouring in the Cordillera is manual.

The two deformation fronts are not coincident because the leading edges of thrust faults deform Mesozoic strata near the surface without significantly displacing underlying Paleozoic strata, which are effectively autochthonous. It is only farther to the west that Paleozoic strata are deformed along the more deeply seated traces of the same thrust faults (see Figs. 2.13 and 3.13 for cross-sectional representations of the thrust geometries).

Atlas Mapping Control

The Western Canada Sedimentary Basin is remarkable in two essential regards. First, there is representative natural exposure of practically all basin strata in the Canadian Rocky Mountains. Proterozoic to Jurassic strata of the cratonic platform and continental terrace crop out extensively in the imbricate thrust sheets that dominate the various ranges of the Canadian Rockies. Synorogenic Jurassic to Tertiary rocks of the foreland basin are extensively exposed in the Front Ranges and the Rocky Mountain Foothills, and locally on the plains. The availability of two- and three-dimensional surface exposure in the deformed belt allows for otherwise unachievable insights not only into the facies and stratigraphic architecture of the rocks themselves but also into the close tectono-stratigraphic relation between the Rockies and the associated sedimentary strata of the undeformed cratonic interior (see Price, *this volume*, Chapter 2).

Second, the subsurface component of the Western Canada Sedimentary Basin is amongst the most comprehensively explored and documented in the world. The density of borehole control is not particularly exceptional (by world standards for oil-bearing basins), but the fact is that data from virtually all of the wells are publicly available from conservation boards and provincial agencies in Western Canada. Most of the data are in digital form. There can be absolutely no doubt that this bank of available subsurface information is truly unparalleled in the world.

In all, there are approximately 200 000 wells that penetrate bedrock in the Western Canada Sedimentary Basin, the vast majority being oil and gas exploration and development wells (the remainder being coal, mineral and water exploration wells). Stratigraphic data (formation tops and marker picks) are available for practically all of these wells (together with reams of petrophysical and engineering data). The opportunities and problems of mapping relate more to the enormity of available information banks than to any dearth of data.

The raw stratigraphic data vary in terms of comprehensiveness and reliability, for they are drawn from the analyses and interpretations of literally thousands of different geologists, over a period of many decades. Most workers in the Western Canada subsurface are familiar with instances of highly suspect or demonstrably wrong information in the raw databases. Experience gained through Atlas data processing and mapping, however, shows that in the overwhelming majority of cases the basic subsurface stratigraphic information is fundamentally sound. The raw databases certainly provide a more than satisfactory starting point for more painstaking regional mapping (see Shetsen and Mossop, *this volume*, Chapter 35, for discussion of the raw databases and their Atlas derivatives).

Rejected Approaches to Mapping One possible approach to Atlas regional mapping would have been to attempt to incorporate all of the data from all of the wells in every Atlas map. This approach was rejected for two reasons. First, the density of data points is uneven. Some townships (six miles by six miles; approximately 10 km by 10 km) contain up to 2000 wells, particularly in the oil sands deposits and in some of the older conventional fields. Other townships contain none or perhaps one. Information clustering of this type introduces grave difficulties in computer gridding and contouring, and in the end does not lead to very satisfying maps, because local details tend to obscure the regional trends. Second, trying to ensure the integrity of all of the relevant picks in every well, even in the context of the large human and monetary resources available to the project, was seen as simply too large a task.

Another possible approach to Atlas regional mapping would have been to deal with the data statistically, by averaging all of the elevation or thickness values in a selected neighbourhood (say one township), discarding the outlying values from the population distribution, weighting the mean or mode as some form of geographic centrum, and mapping on the basis of these township-centrum statistics. This approach was also rejected for one emphatic reason – statistical amalgams do not exist in real space, verifiable in a given borehole. The Atlas database contains only real picks in real wells.

Adopted Approach to Mapping The espoused approach to Atlas mapping is based on the selection of an evenly distributed and demonstrably representative suite of control points. After extensive testing, it was determined that one well per township provides satisfactory control for the Atlas scale of mapping. Criteria invoked for the selection of Atlas control points included total depth, Lithodata coverage, log coverage, stratigraphic representativeness, and assorted secondary parameters. Readers are referred to Shetsen and Mossop (*this volume*, Chapter 35, under Control Points Selection) for details.

By adopting a defined set of "Atlas control wells", the time and resources of chapter authors and map compilers alike were concentrated on maximizing the integrity of the stratigraphic picks in one "reference well" per township. Future users of the Atlas database, commonly with more local or sub-regional applications than the Atlas itself addresses, can use the Atlas control points in a given area as a starting point for more detailed assessments (almost certainly bringing in other wells), knowing that the points controlling a given surface have been assessed by an Atlas chapter team as being internally consistent and regionally significant.

Figure 1.7 shows the locations of the 8857 Atlas control wells. In most townships, the Atlas control well is the deepest or near-deepest well. Some 2735 have Canstrat Lithodata control over at least part of the Phanerozoic interval.

Cordillera Mapping Because of the inherent structural complexities, contouring in the Cordillera was expedited entirely by individual chapter teams. Sections based on borehole intersections in the disturbed belt (Fig. 1.7) proved to be reliable and useful for many Atlas stratigraphic divisions. Measured surface sections also were incorporated into the mapping in many divisions. In all cases, isopach contouring in the disturbed belt reflects palinspastically restored sections. These reconstructions were done by Shell Canada Limited (P. Fermor and R. McMechan) on the basis of extensive company files. Author-submitted localities were assessed for their position in distinct thrust complexes, and the magnitude and direction of deformational displacement were assigned correspondingly. The determination of all restorations from a single source ensures consistency of treatment from division to division. Various map symbols for the locations, together with displacement azimuth lines, depict the palinspastic restorations on Atlas maps.

Plains Mapping In the subsurface of the Interior Plains, Atlas maps are the product of extensive computer automation and database development, manifest through iterative interaction between chapter authors and map compilers (as described above).

Most contour maps are controlled primarily by the "Atlas control wells" (Fig. 1.7), but other data sets are invoked as well. These include the so-called "external sets" and the so-called "standard sets". The origins and uses of these data sets are explained in Shetsen and Mossop (*this volume*, Chapter 35). Flags in the Atlas database indicate precisely which picks are invoked for each contour map.

Attributes and Limitations of Contour Maps

All "principal" Atlas contour maps are regional in scope and character. With very few exceptions all are at 1:5 000 000 scale. Contour intervals conform to the 1, 2, 5 standard – 10, 20, 50, 100, 200, 500 m.

Outcrop regions in the plains are not contoured. Subcrop regions are contoured right to the zero-edges, except in a few cases (e.g., Woodbend and Winterburn maps, Chapter 12).

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 defied by the contours. Some data points are violated simply because it would be neither cartographically pleasing nor conceptually justified to introduce highly localized contour convolutions that obscure or detract from regional contour patterns or, worse, imply a level of mapping precision that is simply not warranted at the Atlas scale. 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 users, particularly for sub-regional or local mapping applications.

Vector Resolution Just as the contours are subject to some generalization, so too are the geological boundaries that appear as vectors or polygons on the principal maps. Subcrop zero-edges, for instance, were drawn by authors on the basis of computer-generated intermediary maps with location postings for both "real" thickness values (finite isopach) and "null" thickness values (isopach interval apparently absent). Given that neighbouring wells may be anything from less than a kilometre to 20 km or more apart, it is obvious why such geological vectors must be considered generalized.

Similar resolution leeway applies to outcrop limits and, to a lesser extent, to oil and gas field outlines. Much broader resolution leeway must be allowed for vectors that are inherently transitional or highly interpretive 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 is supplied with the Atlas. It is provided to allow users a measure of accuracy in 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 have better 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, not local details.

Contouring Protocols for "Structures" In the Interior Plains to the east and northeast of the Cordilleran front, the Western Canada Sedimentary Basin is comparatively free of faulting and folding (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 margin of the Liard Basin in northeastern British Columbia, along the Bovie Lake Fault (see Figs. 3.2 and 3.3, for example).

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/Paleogeology - Nomenclature Maps

Structure Contours Each chapter team was responsible for ensuring the integrity of data controlling the top bounding surface of its division, commonly in consultation with the team(s) for the superjacent slice(s). A structure contour map of that top surface appears in each division chapter. There are 18 such structure contour maps in the Atlas. Because the monoclinal dip of most such Atlas surfaces is comparatively pronounced, the contour interval is generally 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 in the Permian structure map (Fig. 15.13) links at the Permian zero-edge to the -400 m contour of the Carboniferous structure map (Fig. 14.8), and so on. The sub-Mannville unconformity structure map (Fig. 19.3) thus synthesizes all the subcrop parts of the divisions that are truncated beneath the Mannville.

Paleogeology - Nomenclature Each structure contour map shows either subcrop paleogeology, if the surface is an angular unconformity, or applicable stratigraphic nomenclature, if the surface is generally concordant but has sub-regionally variable stratigraphic terminology. Colour- and shape-coded well postings designate the stratigraphic name applicable at control points on the structure surface.

In the case of unconformity surfaces, bands of like postings define the subcrop belts of selected stratigraphic units, truncated at the subject unconformity. Commonly, the authors' interpretations of zero-edge configurations are illustrated by coloured vectors. Examples may be seen in Figures 9.21 (Ordovician-Silurian), 14.8 (Carboniferous) and 16.3 (Triassic). The exception is the sub-Mannville unconformity subcrop, which is depicted by coloured polygons (Fig. 19.3).

In cases of generally concordant surfaces, colour patterns in the postings are normally somewhat diffuse, for they reflect how the usage of stratigraphic names varies transitionally from one subregion to the next, as a function either of nomenclatural rank (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 Mannville division (Fig. 19.21), for example, is generically designated over wide areas as Mannville Group or Blairmore 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 map may be seen in Figures 13.35 (Wabamun) and 21.3 (Viking).

It should be noted that some of these so-called "concordant" surfaces are actually unconformities or disconformities, 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 digitized polygons based on pool data supplied by the relevant provincial agencies, compiled for the Geological Survey of Canada by P. Hay in cooperation with Digitech Information Services, finalized for the Atlas maps by D. McPhee. Details of the conduct and results of the compilation are contained in Hay (*this volume*, Chapter 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, together 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 numbered 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 designations of stratigraphic divisions; that is, 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 broken down into three different stratigraphic intervals, and the Mannville (Chapter 19), where the oil and gas fields are 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 resolution of the hydrocarbon fields. Thus, in the Wabamun (Fig. 13.35), the Permian (Fig. 15.13) and two of the three prominent Colorado Group sandstones (Viking, Fig. 21.3; Dunvegan, Fig. 22.2) hydrocarbon fields are shown on the corresponding structure contour maps.

Isopach and Lithofacies Maps

Atlas isopach maps, be they division maps or subdivision maps, are the product of compilation by "point subtraction". For each and every control point on a given map, the depth of the top surface is subtracted from the depth of base surface to yield the total thickness z-value for that control point. Contouring is based solely on the thickness z-values thus obtained. The alternative approach is "grid subtraction", wherein the top and base surfaces are grided separately, and the isopach is derived from subtraction of grid nodes. The advantages of the grid subtraction, which are manifest mostly in modelling applications, are for Atlas purposes outweighed by the disadvantages associated with using interpolated grid values instead of real (and verifiable) thicknesses at control points. Thus the principle of mapping on the basis of real picks in real wells is sustained. Exceptions to this rule occur in some uppermost Cretaceous-Tertiary maps where, in order to compensate for the paucity of up-hole control, grid subtraction is utilized.

Division Isopach Maps There is one gross interval isopach map for each Atlas division. It embraces all of the strata between the top and base bounding surfaces. Stratigraphic definition of these surfaces, based on criteria agreed to at the beginning of the project, is discussed in the various Atlas chapters and tabulated in the Atlas database. As described above, most of the division isopach maps are overprinted with outlines of the relevant oil and gas fields.

Thickness variations in most Atlas divisions are sufficiently pronounced to warrant contouring at relatively coarse intervals, typically 20 or 50 m. Where division isopach contours are extended into the disturbed belt they are shown in brown (as opposed to black on the plains), and in some instances have wider contour intervals.

Subdivision Isopach Maps Most of the 19 Atlas divisions are amenable to further breakdown into stratigraphic subdivisions. Isopach maps for 48 subdivisions are contained in the Atlas. The bounding surfaces for subdivisions are at least as carefully controlled as those bounding the divisions. Stratigraphic definition of the picks controlling subdivision surfaces is set out in the text of Atlas chapters and specifically defined in the Atlas database.

For purposes of map compilation, certain Atlas divisions are not subdivided. These include: the Devonian Elk Point Group (Chapter 10), where the internal subdivisions are depicted in a series of paleogeographic maps rather than as isopach and lithofacies maps; the Devonian Beaverhill Lake Group (Chapter 11), where the internal stratigraphy is portrayed as an initial transgressive phase and a subsequent regressive phase; the Devonian Wabamun Group (Chapter 13), where alternative isopach and lithofacies mapping techniques are applied; and the Permian (Chapter 15), where the limited overall thickness and confined areal extent in the plains obviate the need for further differentiation.

The cartographic protocols described for the division isopach maps also apply to the subdivision isopach maps (relating to zero-edges, contours in the Cordillera etc.). Typical contour intervals for subdivision isopachs are 10, 20 and, exceptionally, 50 m.

Lithofacies Maps Most of the 48 Atlas subdivision isopach maps are overprinted with coloured domains depicting lithofacies. The illustrated lithofacies are based on Atlas processing of the voluminous Canstrat Lithodata files (made available to the project by Canadian Stratigraphic Service Ltd. through Home Oil Corporation). The exception is the Woodbend-Winterburn subdivision maps, where the chapter team furnished independently derived lithofacies portrayals.

Colour coding of the lithofacies domains generally conforms to the Atlas lithology/lithofacies standards (Fig. 1.1), with quite a number of colour hybrids introduced for mixed lithologies. For example, highly argillaceous limestones are in greenish-blues, mixed dolomites and evaporites in pinkish purples. Various browns and rusts are introduced where the lithological mixing is so pronounced as to defy spectral blending.

On any given lithofacies map, details of the portrayed lithofacies are set out in the accompanying title block legend, which contains descriptions not only of basic lithologies but also significant petrological characteristics (colour, grain size, sorting, significant accessory constituents, and diagenetic components such as cements), as well as limited paleontological information (key fossils and frame-builders) and significant petrophysical characteristics (porosity, permeability). There is also some indication of the degree and scale of interbedding and, where appropriate, the vertical variability of lithological constituents (e.g., "increasingly dolomitic toward the top").

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

The Canstrat Lithodata file is of course based on analysis of well cuttings, and therefore is subject to all of the inherent potential pitfalls and limitations (cavings contamination, constraints on the recognition of fossils, etc.). Additional limitations and uncertainties relate to lithofacies characterization in very thin zones (near subcrop zero-edges) where percentage data become erratic (depending on just what lithology is fortuitously preserved in the zone of converging unconformities). This latter difficulty is commonly circumvented in Atlas lithofacies maps by labelling rim zones simply as "variable lithology in thinner zones".

The Lithodata information does not readily distinguish between inherent (depositional) lithology and secondary (diagenetic) constituents. For example, in working with the inset statistical tables, users are cautioned that entries such as Chert may reflect either bedded 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 processing shows the Canstrat Lithodata file to be remarkably sound in terms of data integrity and consistency. Atlas-derived lithofacies domains complement and reflect very closely the subsurface experience of authors, whose facies studies (though commonly in comparatively local areas) are based on exacting analyses of cores and geophysical log suites. In the writers' experience, inferences drawn from Lithodata processing are reliable, certainly the best available for extended stratigraphic sections where cores are generally lacking.

Wells with Canstrat control of the subject interval are indicated by triangles on the lithofacies maps (circles are used for wells with stratigraphic control only). Users will note that the density of Canstrat control is at least an order of magnitude greater in Alberta and British Columbia than it is in Saskatchewan and Manitoba. Inferences drawn from the lithofacies maps should be tempered accordingly.

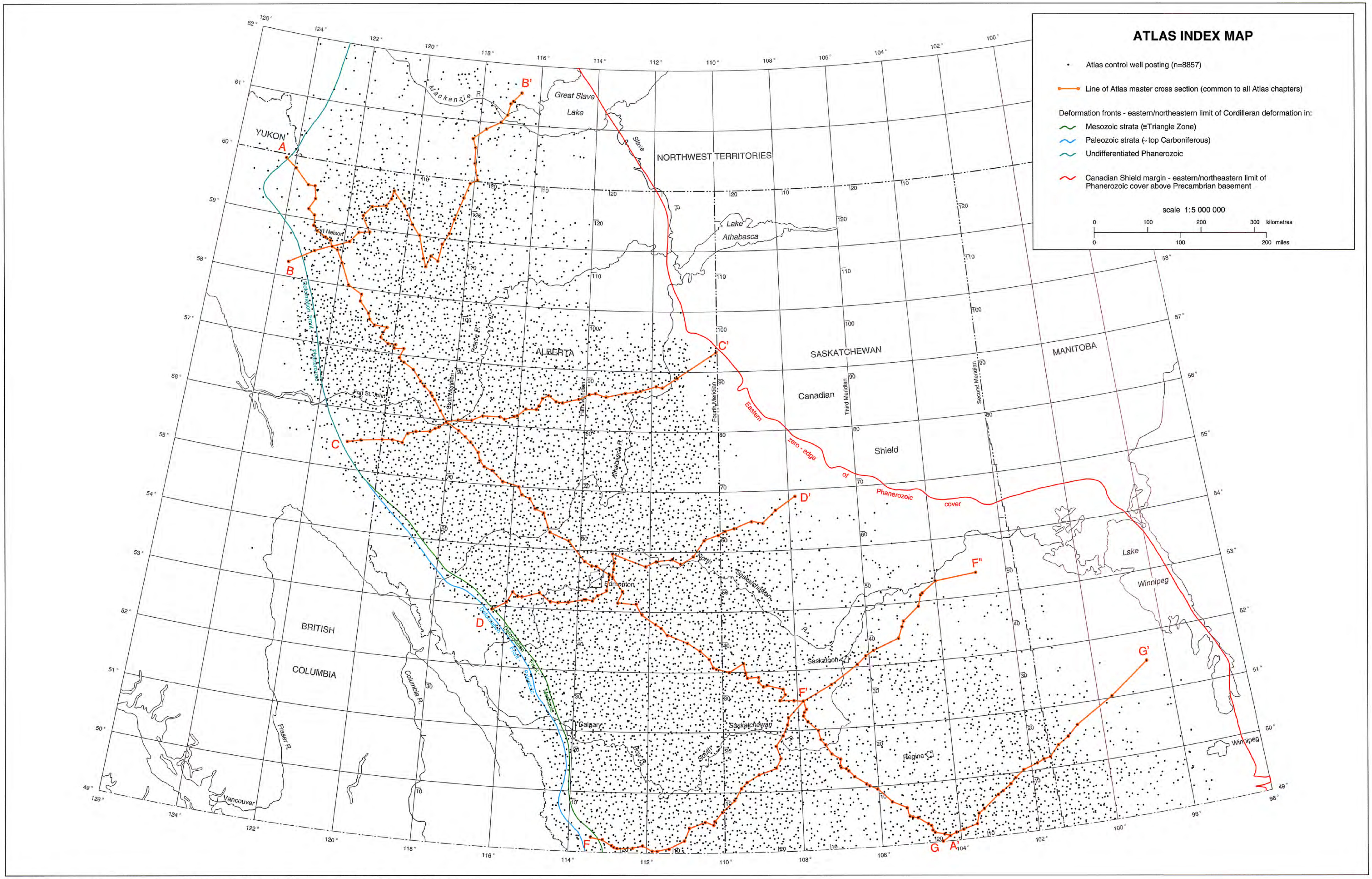

Figure 1.7 Index map of Atlas subsurface control, showing the designated "Atlas control wells" and the lines of regional "master" cross sections.

Individual Lithology Maps The lithofacies domains derived for Atlas maps are of course amalgams, embracing all constituent lithologies. Amongst the natural by-products of Atlas Lithodata processing, however, are maps of the percentage distribution of individual lithologies: sandstone, dolomite, anhydrite, etc.; or maps of combined components such as "fine-grained clastics" (shale plus siltstone) or carbonates (limestone plus dolomite, plus in some cases marlstone).

Most chapter teams preferred to limit their lithofacies mapping to the principal domain amalgams, but some chose to illustrate as well the spatial distribution of individual component lithologies. These individual lithology maps are at 1:10 000 000 scale (Cambrian, Figs. 8.20a-d; Wabamun, Fig. 13.4) or, in one case, at 1:5 000 000 scale (Permian, Figs. 15.15 and 15.16).

Paleogeographic Maps

Practically all Atlas division chapters contain one or more paleogeographic maps (see the Index at the back of the volume). Some are highly schematic, almost conceptual. Others are more detailed and more exactingly controlled. All are colour-coded in general accordance with the Atlas colour chart for depositional environments and paleogeography (Fig. 1.5). They are solely author-compiled, without any direct reference to the Canstrat Lithodata file or its Atlas-processed derivatives.

Inherent in all of the paleogeographic maps are the difficulties associated with attempting to depict shorelines and depositional tracts that commonly shifted over time, on a map that instinctively connotes an instant in time. Problems associated with construction of paleogeographic maps that portray perhaps several million years of paleogeographic evolution are discussed by Smith (*this volume*, Chapter 17).

Atlas Cross Sections and Reference Logs

In a geological atlas, cross sections are at least as important as maps. They can be thought of as vertically-oriented maps, showing thickness and superposition relations just as a map would for an upturned succession. More importantly, cross sections depict correlations and illustrate the log signatures upon which those correlations are based. Just as correlations are the most basic building blocks of the science of stratigraphy, so cross sections are the most basic manifestations of stratigraphic analysis.

Regional Cross Sections

Of the 190 cross sections in the Atlas, about two-thirds are regional in scope, spanning most or all of the subsurface extent of the subject strata. They were constructed at condensed log scale – 1:1200 (1 cm=12 m, 1"=100') – and reduced to 20 percent for publication – 1:6000 (1 cm=60 m, 1"=500'). Horizontal scales, measured as true horizonal distances from well to well, as opposed to projecting wells onto a straight-line trace, are more variable. In general, however, sections were constructed at 1:500 000 (1 cm=5 km), which when reduced to 20 percent for publication yields 1:2 500 000 (1 cm =25 km). Thus, most regional cross sections have vertical exaggeration of approximately 400 times (1:6000/ 1:2 500 000). In the absence of designation to the contrary, in the figure caption or on the illustration itself, these standard vertical and horizontal scales can be taken as applying to all regional cross sections. Bar scales on the sections may be used to verify dimensions.

There are two reasons for applying standard cross section scales throughout the Atlas. The first is a strictly practical one. The thickest sections, typically located in the Cordillera, need to fit the vertical image dimension of the Atlas page – about 32 cm (≡1920 m); 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 or philosophical, 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, Fig. 15.12) can be directly compared to thicker 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 1:5 000 000, so the Atlas regional cross sections are standardized at 1:6000 and 1:2 500 000, to facilitate comparison.

Master Sections Figure 1.7 shows the transect lines for the six so-called "master cross sections" – longitudinal section A-A', and transverse sections B-B', C-C', D-D', F-F' and G-G'. The lines of section purposely replicate the structural cross sections published when the Atlas project was getting under way (Wright, 1986; see also Fig. 3.4). Atlas master sections are stratigraphic, as opposed to structural, and each one is referenced to an author-selected datum. The lines of section are common from chapter to chapter so as to allow users to compare the correlations and stratigraphic relations in one division with those in adjacent divisions (by reference to preceding and succeeding chapters).

Certain master sections are missing from some division chapters, either for the obvious reason that the line of section does not intersect any strata of the subject division, or because the line of section distorts depositional trends or facies relations. In the latter case, alternate sections are substituted (see Discretionary Sections, below).

Standard graphic elements for the master cross sections include: prescribed headers showing the appropriately spaced locations of all wells on the line of section, regardless of whether or not they were all used in construction of the section (see discussion below); labelled horizonal datum; applicable stratigraphic nomenclature and (where appropriate) age; insert index map, with the subject section highlighted in red; and standard vertical and horizontal bar scales. Most sections have three different line weights, the heaviest for correlation lines that distinguish one formal stratigraphic unit from another, the intermediate weight for standard (intra-formational) correlations, and the finest weight for the log traces (although users will note that, on magnification, these can be quite variable, either because of inconsistencies in initial drafting or because of variable resolution in digital scanning of the traces). Solid lines indicate established correlations, with broken lines indicating either approximate or assumed correlations. Colours on the correlated sections depict lithology or lithofacies (see Fig. 1.4), not depositional environment or age.

On average, log traces are shown for every third or fourth well on the master sections, for it is impossible to show a trace for each and every well. Where intermediary wells are used for correlation (log trace not shown), a dot appears on the correlation line. No dot beneath a header well indicates that that well was not considered in constructing the section. All log traces are gamma ray unless otherwise indicated on the figure or in the caption.

Discretionary Sections The master cross sections are intended to establish a network of consistent and compatible regional correlations throughout the length and breadth of the basin, as a matter of common reference, chapter after chapter. The alternate or "discretionary cross sections", on the other hand, are unique to specific chapters. They were consciously selected by chapter teams to illuminate if not exemplify the regional stratigraphy of that slice. They are oriented to take into account known depositional trends or facies transitions. In a few chapters (e.g., Elk Point Group, Chapter 10), discretionary regional sections dominate to the near exclusion of master sections, but in most division chapters there is something approaching an equal blend.

Scales for the discretionary regional sections are more variable than those prescribed for the master sections. Nevertheless, they generally conform to the 1:6000/1:2 500 000 Atlas standard.

Graphics standards for the regional discretionary sections (labelling, line weights, colours) are the same as for the master cross sections (see discussion above).

Schematic Sections A number of Atlas chapters feature one or more regional cross sections that are not strictly log-based. These schematic sections are intended to illustrate regional stratigraphic relations in an unencumbered way, for purposes that are more conceptual than they are precise or detailed. Examples occur in division chapters (e.g., Mannville Group, Fig. 19.11) and theme chapters (e.g., Coal Resources, Figs. 33.3 and 33.4).

Sub-regional and Local Cross Sections

Local and sub-regional cross sections, like Atlas maps of the same ilk, are intended to illustrate geological relationships at scales that allow readers to grasp the basis for extrapolation to Atlas regional scales. Many span deposits of economic importance, as examples of the geological configurations that characteristically give rise to hydrocarbon traps or mineral deposits (see for instance Fig. 21.12 through the Viking Crystal and Joarcam fields; and Fig. 3.19 in the Pine Point lead-zinc ore body).

Seismic Sections

These are few and far between in this Atlas, for there already exists a comprehensive *Geophysical Atlas of Western Canada Hydrocarbon Fields* (Anderson et al., 1989). The seismic sections illustrated in this volume are generally limited to depiction of large-scale structures (e.g., the Dunvegan Fault, Fig. 3.8; the Fort St. John Graben system in the Carboniferous, Fig. 14.6).

Few basin-scale seismic sections have been compiled for Western Canada, and none appears in this volume. Readers are referred to Zhu and Hajnal (1993) for one published example, and to Ross (1993) for the Lithoprobe Alberta Basement Transects.

Reference Logs

In published stratigraphic analyses in the subsurface, few things are more frustrating than insufficient illustration of exactly what geophysical log signatures are picked for correlation purposes. Therefore, each division chapter in the Atlas devotes one or more figures to depicting suites of "reference logs". These typically contain a gamma-ray trace, as the standard for correlations shown on the Atlas cross sections, together with two or three other characteristic traces (e.g., resistivity, S.P., sonic, neutron). Many also show a lithology column. Practically all reference logs are at 1:3000 vertical scale, for ease of thickness comparison from one division to another. This scale represents a reduction to 40 percent from the condensed scale on commercially available logs and a two-fold expansion from the standard vertical scale for regional cross sections.

Logs for at least one reference well appear in each division chapter, and some chapters have as many as a dozen, depending on internal subdivision breakdown and facies variability. Locations of reference wells are cross-referenced to the chapter index map and/or to appropriate columns in the chapter correlation chart.

Additional Illustrations

Apart from the Atlas maps, cross sections, and reference logs, there are over 200 additional illustrations. Some are standard, but most are discretionary.

Stratigraphic Division Chapters

Correlation Charts Each division chapter contains a correlation chart showing the stratigraphic subdivisions and the nomenclature used in that chapter. Charts contain up to eight columns for various sub-regions in the subject subcrop area. Readers should note that although stratigraphic names used in the text and in the associated maps and cross sections are all placed on the correlation chart, there is no attempt to illustrate comprehensively all of the stratigraphic names that can be legitimately applied to the subject strata (as per the Lexicon of Western Canada; Glass, 1990). Neither is there any attempt to illustrate or describe the historical evolution of stratigraphic names, as one might expect in a journal paper on new or revised nomenclature. Some "informal" stratigraphic designations appear in the correlation charts (e.g., the so-called V-marker in the Silurian, Fig. 9.4), but no new nomenclature is herein formally introduced.

Relative ages are indicated in most cases to the stage or sub-stage level. Where possible and appropriate, biostratigraphic zonations are illustrated (e.g., Fig 18.4 in the Jurassic) but there is no attempt at comprehensive biochronological characterization of all zones. Where absolute ages appear in the correlation charts, they are based on the Decade of North American Geology (DNAG) designations (Palmer, 1983). Exceptions to this rule are noted in the accompanying caption or on the figure.

Schematic Illustrations In addition to schematic cross sections, many division chapters contain idealized or conceptual diagrams. Most prominent amongst these are depositional models, shown either in two dimensions (e.g., Carboniferous carbonate ramp and shelf models, Figs. 14.17 and 14.18) or in three-dimensional block diagrams (e.g., Triassic Charlie Lake depositional environments, Fig. 16.10).

Discretionary Figures Other discretionary figures are too disparate to itemize here. They are purpose-specific and self-explanatory. For reasons that relate more to the regional scale of the Atlas than anything else, there are very few photographs (see exceptions in Figs. 33.5 - 33.9, coal deposits; and Fig. 9.29 of the Tyndall buildingstone quarry, for example).

Theme Chapters

Some theme chapters are dominated by maps (Chapters 7, 17, 29, 30 and 31, for example), others by cross sections and schematic illustrations (e.g., Chapters 25 and 35, respectively), but most illustrations in theme chapters are purpose-specific.

Tables

Although the data-intensity of the Atlas is, overall, very high, little data are published here. They exist in the Atlas database (see Shetsen and Mossop, *this volume*, Chapter 35). Certain resource data, however, require printed tabulation for direct and immediate reader reference. Thus, Chapter 34 (Hamilton and Olson, *this volume*) contains large data tables on both metallic and industrial mineral occurrences; Chapter 33 (Smith et al., *this volume*) contains statistical data tables on coal resources; and Chapter 32 (Hay, *this volume*) contains tables of summary statistics for oil and gas occurrences in the basin. The only other chapter with extensive data tables is that dealing with in-situ stress (Bell et al., *this volume*, Chapter 29), 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/underlying 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 most 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, paleophysiographic features).

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

Thickness/Lithology - discussion of the chapter's division isopach, with its overprinted oil and gas fields, and explanation of each of the subdivision maps, from the base upward, including discussion of illustrated lithofacies patterns and paleogeographic implications.

Sub-regional and Local Relationships - introduction and elucidation of maps, cross sections and related figures (the so-called "zoom-in" illustrations) that exemplify the facies-scale foundations for the regional stratigraphic architecture, or epitomize the kinds of energy or mineral deposits that make the division economically important.

Discussion - commentary on the depicted geology and geological history, plus synthesis interpretations and ideas on further research.

Acknowledgements - chapter-specific acknowledgements of authors' colleagues, families, reviewers and the like, recognizing that project-scale acknowledgements are contained in the Atlas foreleaf pages.

Theme Text

Unlike the systematic regimen of headings and sequencing that characterizes division chapters, there are no set guidelines for the context and flow of text in theme chapters. They are generally designed to read like review papers prepared for a journal, more copiously illustrated perhaps, and with the luxury of large coloured figures where justified. Like the division chapters, the illustrations embody all of the main threads of the authors' intents, with the text devoted to explaining the figures in a logical progression and providing readers with appropriate references to further reading.

Discussion

This Atlas is reconnaissance in scale and generalized in nature. It is not intended to supplant the detailed, commonly site-specific geological analysis that on a day-to-day basis epitomizes our collective quest to find and develop earth resources in an environmentally sustainable way. Rather, it is intended to provide the background, the foundation, the context, for that ongoing work.

As a reference volume, the Atlas is expected to have a long shelf life. It must stand the tests of time and demonstrate its utility even in the face of changing paradigms. The rocks do not change; only our ability to understand them. Thus, although the Atlas contains much new data and many new ideas and approaches, its essence is determinedly factual and descriptive.

It is hoped that the very act of marshalling and synthesizing in one place our collective knowledge of the regional geology of the Western Canada Sedimentary Basin will foster the development of a whole new generation of ideas and perspectives on the nature and origin of the basin and its contained resources. Goodness knows we've still got lot to learn.

Further Reading

References in individual chapters provide access to most if not all of the important modern literature on the regional geology of the Western Canada Sedimentary Basin. Recommended additional reading on the nature and origin of the basin includes: the original atlas (McCrossan and Glaister, 1964), most of the contents of which remain as valid today as when they were published; Ricketts (1989), a case history of the nature and origin of the Western Canada Sedimentary Basin; Macqueen and Leckie (1992), a book on foreland basins and fold belts, three quarters of which is devoted to the foreland basin of Western Canada; Stott and Aitken (1993), the Decade of North American Geology volume on the cratonic cover of Western Canada; and Caldwell and Kauffman (*in press*), a book on the Mesozoic Western Interior Basin.

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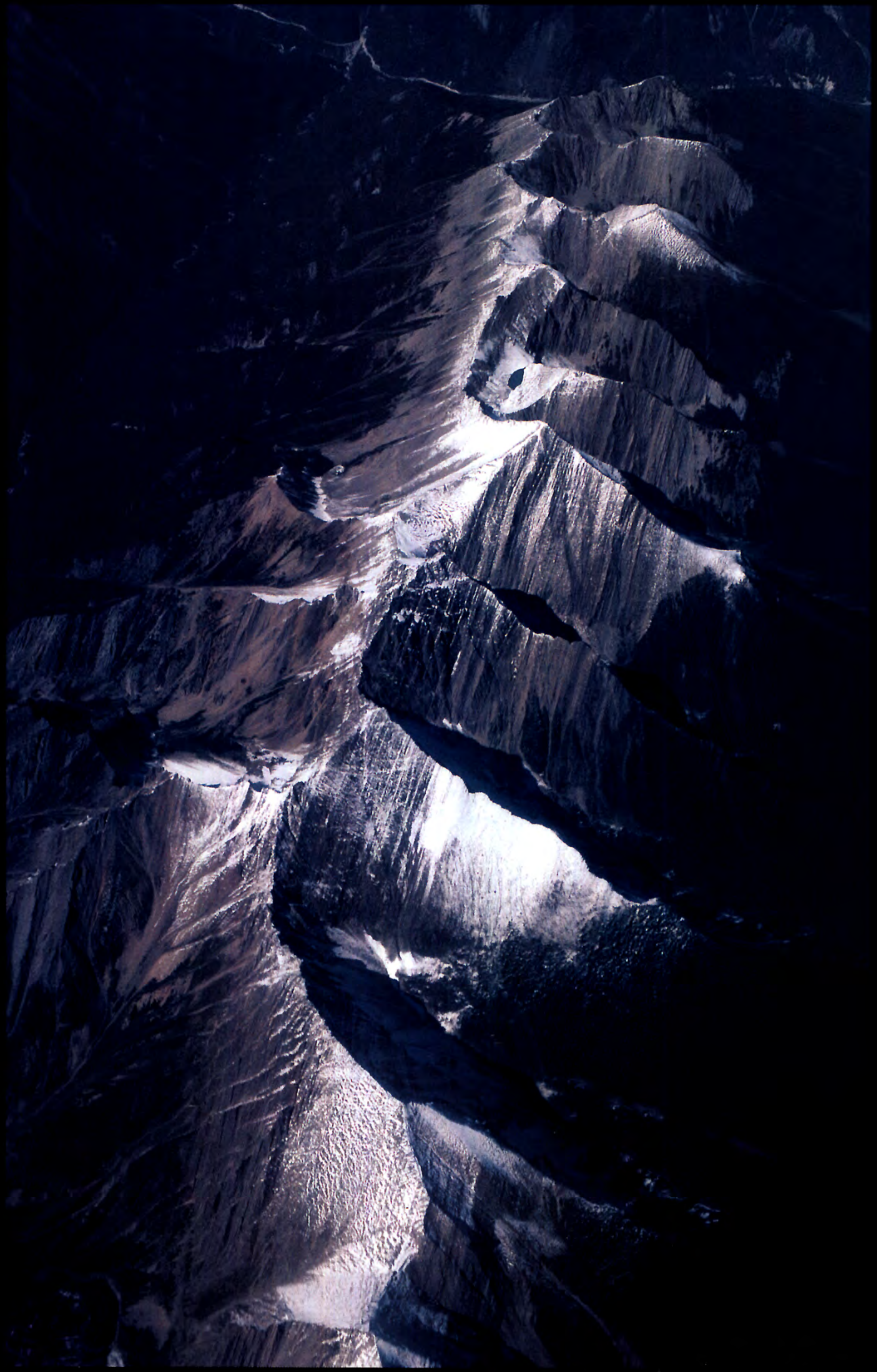

Frontispiece 2.0 The Cordillera. Aerial oblique of upturned Ordovician Beaverfoot Formation strata in the Quin Range southeast of Golden, British Columbia. The Rocky Mountain Fold and Thrust Belt constitutes the deformed western and southwestern edge of the Western Canada Sedimentary Basin. Basin evolution is intimately related to the tectonics of the western margin of ancient North America and to the development of the Cordillera. Photograph by G.D. Mossop.