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GEOLOGIC STRUCTURE OF THE CANADIAN ROCKY MOUNTAINS BETWEEN BOW AND ATHABASCA RIVERS — A PROGRESS REPORT

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ABSTRACT

The preliminary results from a reconnaissance study of regional geology over an area of some 12,000 square miles, together with available information from nearby regions, are appraised and form the basis for this outline of the structure of part of the Rocky Mountains. The fundamental genetic relationship between the Rocky Mountains and the rest of the Cordillera, and the important role that data from the Rocky Mountains can play in elucidating the structural evolution of the whole Cordillera are emphasized.

The distinctly layered and strongly anisotropic mass of rock deposited within the Cordilleran miogeosyncline and on the shelf along the margin of the craton has been stripped along the layering from its crystalline basement. The mass has moved upward and up to at least 125 miles northeastward along an array of discrete, discontinuous, interleaved, and overlapping thrust faults, out of the region now occupied by plutonic rocks of the Eastern Crystalline Belt of the Cordillera, to where it is now stacked up on the flank of the craton in the thrust sheets typical of the Rocky Mountains. This process of northeasterly foreshortening involved more than 8 kilometers of crustal thickening that is restricted to the suprastructure of bedded sedimentary rocks above a passive infrastructure of crystalline basement rocks. It was followed by a much less important phase of block faulting that involved northeasterly extension.

Thrusting in the Rocky Mountains is a high-level manifestation, along the foreland-margin, of the same deformation that is expressed at depth to the southwest by the diapiric northeastward rise of an infrastructure of tongues of hot mobile, gneissic rocks. Shuswap-type gneisses that emerge from beneath Proterozoic metasedimentary rocks along the Purcell thrust occur on the west side of the main structural culmination within the Rocky Mountains where they have been thrust over Cambrian and Proterozoic rocks. They are outlined within this suprastructure by a halo of regional metamorphism that extends northeast far into the Rocky Mountains and can be dated as pre-Albian (Lower Cretaceous). Structures in the Main Ranges congruous with the tongue of gneiss and its metamorphic halo outline a culmination and a deflection of the structural grain that apparently pre-date the waning phases of the metamorphism and are not represented in the Front Ranges and Foothills where the deformation must be younger than this metamorphism.

A structure section through the Rocky Mountains affords a basis for reconstructing the form of the pre-Upper Jurassic sequence of miogeosynclinal and shelf deposits as they existed prior to deformation. Much of the thrusting in the Rocky Mountains occurred in the thinner sequence on the shelf and its cover of clastic wedge deposits. Almost all of the rock eroded from the miogeosyncline-shelf sequence came from what are now the Main Ranges and the western Front Ranges. The former locus of a hinge zone at the edge of the Cordilleran miogeosyncline corresponds approximately with the present site of the Rocky Mountain Trench. Beyond this the steeper southwesterly slope of the basement marking the flank of the geosyncline occupied the site of what is now a major structural and metamorphic culmination in the Eastern Crystalline Belt.

A variety of contrasting structural styles and local structural histories within this part of the Cordillera can be integrated in terms of a simple model for structural evolution that involves a continuing process of progressive buoyant upwelling and lateral spreading of a hot mobile infrastructure beneath a relatively passive suprastructure in the Western Cordillera, and equivalent progressive northeasterly growth of the foreland thrust belt that forms the Rocky Mountains. The lateral spreading is a gravitational phenomenon that involves the entire mass, including thrust plates in the Rocky Mountains which have moved up the basement slope in response to it. Shortening due to thrusting in these mountains should be equated with lateral spreading in the upwelling infrastructure, and is not necessarily a measure of actual crustal shortening.

The popular concept of an Early Tertiary Laramide orogeny that produced the structure of the Rocky Mountains, and a separate earlier orogeny that was restricted to the rocks of the Western Cordillera is not implicit in the structural relations and stratigraphic record from which it was drawn. The northeasterly growth of the Rocky Mountains appears to have proceeded conjointly, step by step, with equivalent deformation in the infrastructure of the Western Cordillera during the interval from Late Jurassic to Eocene. Erosion of the sequence of miogeosynclinal and shelf deposits in the Rocky Mountains expanded northeasterly with the deformation and contributed significant volumes of detritus to each of the various components of the Late Jurassic to Paleocene clastic wedge sequence.

INTRODUCTION

Over large tracts of the southern Canadian Rocky Mountains, the basic information on which appraisals of the geologic structure and tectonic evolution have been based consisted of isolated and widely scattered studies made adjacent to the main travel routes. The first systematic information on the regional geology of the area has become available during the past decade as a result of helicopter-supported regional geologic investigations which embraced the less accessible parts of the Rocky Mountains between the main travel routes. One of these helicopter-supported regional studies, the Geological Survey of Canada's Operation Bow-Athabasca, involves the systematic investigation of about 12,000 square miles of the Rocky Mountains in the region of Bow and Athabasca Rivers. Our purpose here is to present a progress report on Operation Bow-Athabasca, by outlining our present understanding of the structure of this part of the Rocky Mountains in terms of the preliminary results of this investigation, together with the available information from the surrounding region, and by examining the implications of this on our understanding of the structural evolution of the southern Canadian Cordillera as a whole.

Operation Bow-Athabasca (Price and Mountjoy, 1966; Price, 1967 and 1967a) consists of studies of the regional geology and various aspects of the geologic structure by R. A. Price, E. W. Mountjoy, H. R. Balkwill, D. G. Cook, J. D. Aitken, and H. U. Bielenstein. These investigations are supplemented by earlier and concurrent, more detailed, studies of: the pre-Devonian stratigraphy (Aitken, 1963, 1966, 1966a, 1968; Aitken and Greggs, 1967; Aitken and Norford, 1967), the structural relations between the carbonate and slate facies of the lower Paleozoic succession in the vicinity of Field, British Columbia (Cook, 1967), the structure of the Western Ranges of the Rocky Mountains near Golden, British Columbia (Balkwill, 1968), the structural relations of a metamorphic complex along the Rocky Mountain Trench at Canoe River (Giovanella, 1968), Permo-Carboniferous stratigraphy (Macqueen, 1967; Macqueen and Bamber, 1967), Ordovician and Silurian stratigraphy (Norford, 1964, 1969), Cambrian biostratigraphy (Aitken and Fritz, 1968), Devonian stratigraphy (Mountjoy, 1968), and Triassic stratigraphy (Gibson, 1967).

Throughout most of the area the basic procedure during the investigation has been the preparation of geologic maps at a scale of 1:50,000. These are based on studies of vertical air photographs, supplemented by air and ground observations and detailed information on representative stratigraphic sections. The detailed information arising from the stratigraphic studies consists of definitions of the rock units and their mutual stratigraphic relations, and descriptions of the stratigraphic succession at hundreds of individual localities. It provides a basic framework for the photogeologic interpretations and the ground and air observations that have been used to confirm and amend them. The various thin, distinctive, and laterally persistent lithostratigraphic units which comprise the stratigraphic succession in the region can generally be traced with ease and precision on the air photos over and between the extensive areas of rugged alpine terrain that provide excellent and widespread exposure of bedrock. Over parts of the western Rocky Mountains thick successions of upper Precambrian (Hadrynian) metasedimentary rocks and lower Paleozoic shale and slate contain fewer thin distinctive rock units and are more homogeneous on the scale of the air photos, and bedrock is more frequently masked by a widespread cover of dense vegetation. There, the delineation of the structure is based on traditional reconnaissance, ground traversing techniques, supplemented by air observations and photogeologic interpretation, and, accordingly, is less precise.

The geologic structure of the Rocky Mountains in the region between Bow and Athabasca Rivers is outlined in a regional map (Figure 2-1, in pocket at rear), and an accompanying structure section, enlarged to twice the scale of the map. The area covered by this map is equivalent to that of the combined Swiss, French, and Italian Alps. Its location, in relation to the main tectonic subdivisions of this part of the Cordillera is shown in Figure 2-2. The map is based mainly on a preliminary appraisal of information obtained by Operation Bow-Athabasca, most of which is represented in more detailed, but still incomplete, maps prepared in conjunction with the operation. Around the periphery of the area studied by Operation Bow-Athabasca, it incorporates information from the series of more detailed maps that have been published by the Geological Survey of Canada, and from unpublished maps prepared by R. J. W. Douglas, E. W. Mountjoy, J. O. Wheeler, and R. A. Price. The structure section accompanying the map is discussed in detail below.

STRATIGRAPHIC FRAMEWORK

Two main sequences of rocks are represented within this part of the Cordillera: a miogeosyncline-shelf sequence that ranges in age from Windermere (Late Precambrian-Hadrynian) to Late Jurassic, and a clastic wedge sequence of Late Jurassic to Early Tertiary age. Some of the more recent detailed information on the stratigraphy is presented in the papers cited above, and a comprehensive review of the stratigraphy of the entire western Canada sedimentary basin has recently been published (McCrossan and Glaister, 1964). Only certain salient features of the stratigraphy will be considered here.

The miogeosyncline-shelf sequence consists predominantly of marine deposits, and is dominated by shallow-water carbonate rocks. How-

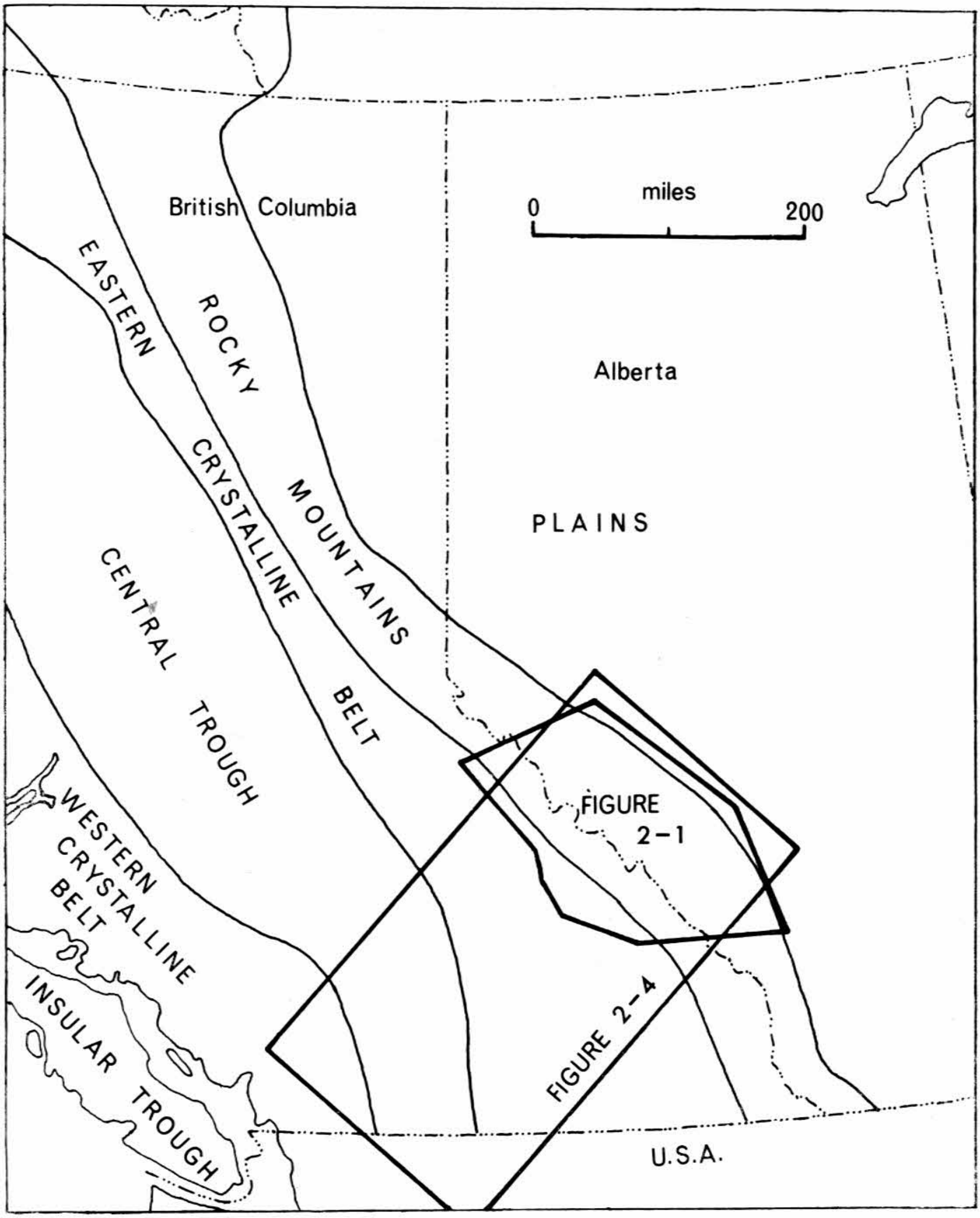

Figure 2-2: Index map with main tectonic subdivisions of the southern Canadian Cordillera.

ever, it does contain appreciable amounts of terrigenous clastic rocks, most of which have a northeasterly provenance and represent material transported from the interior of the craton toward the Cordilleran geosyncline. The base of this sequence is characterized by a succession of sandstones and kindred clastic rocks which transgressively onlap the crystalline basement rocks that extend under the Plains from the Canadian Shield. Within the mountains the oldest known components of this basal transgressive facies, the Lower Cambrian Gog Group and the underlying Miette Group and equivalent rocks, are the oldest rocks exposed and are nowhere seen in depositional contact with the crystalline basement. The total thickness of the