U.S. DEPARTMENT OF INTERIOR

GEOLOGICAL SURVEY

Measured Sections of the Cambrian Sawatch Quartzite and Peerless Formation, and the lower part of the Ordovician Manitou Formation, Manitou Springs Area, Front Range of Colorado

by

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Introduction

This report presents detailed surface sections measured by the authors as well as descriptions of lithofacies and a preliminary interpretation of depositional environments as part of an ongoing investigation into the stratigraphy, sedimentology, and petrology of the Cambrian System in Colorado.

In the area of study (Figure 1), the Cambrian Sawatch Quartzite and Peerless Formation together vary from 16 to 20 m (53 to 65 ft) in thickness. The Sawatch nonconformably overlies the Proterozoic Pikes Peak Granite. The Peerless is overlain by dolomite of the Early Ordovician Manitou Formation.

Most previous reports (Brainerd and others, 1933; Maher, 1950; Berg and Ross, 1959; Berg, 1960; Bush, 1973; Ross and Tweto, 1980) described the Sawatch and Peerless in less detail than we do in this report. Recent reconsideration of Cambrian sandy sedimentary environments at other locales (as examples, Driese and others, 1981; Dott and others, 1986; Fedo and Prave, 1991; Prave, 1992) has led to reinterpretation and recognition of complex facies patterns in closely associated rocks. Such examination of complex facies patterns relies on the detailed stratigraphic and lithologic descriptions that we present here.

The present study is part of an analysis of Cambrian and Ordovician reservoir and source rocks in the Rocky Mountain region. Studies of reservoir facies and organic geochemistry of prospective source rocks will be published elsewhere. Of particular interest is the investigation of reservoir characteristics of Lower Paleozoic sandstones and how those characteristics differ from sandstones of later ages, after the introduction of terrestrial flora.

Stratigraphy

The Sawatch Quartzite was originally named by Eldrige (1894) for Cambrian rocks along the western margin of the Sawatch Range in central Colorado. The Sawatch averages 46 m (150 ft) in the Sawatch Range where it is composed of quartz-rich sandstone and conglomeratic sandstone (Stevens, 1961). It is commonly glauconitic, especially in the upper part, and may contain abundant feldspar grains. Anderson (1970) subdivided the Sawatch of the southern part of the Mosquito Range in central Colorado into a basal coarse-grained unit, and an upper quartzitic sandstone unit. He identified an upper crossbedded medium-grained sandstone unit in the northern part of his study area. In the area of this study, the Sawatch is composed of light-colored planar-bedded quartzarenitic and subarkosic sandstone and conglomeratic sandstone. Lithofacies units A and B (Lithofacies section below), which make up the Sawatch, together average about 5 m (16 ft) thick. The lower contact of the Sawatch is sharp and forms a nonconformity with underlying Proterozoic granite. The upper contact was considered gradational by most workers (including Stevens, 1961; Anderson, 1970; Bush, 1973). We have placed the top of the Sawatch at a sharp lithologic break separating typical Sawatch lithologies from overlying reddish-brown weathering dolomitic sandstones and interbedded siltstones and shales of the Peerless Formation. This sharp break is recognized at each of the four measured sections presented in this report. The Sawatch Quartzite is lithostratigraphically equivalent to the Ignacio Quartzite of southwestern Colorado, the Lodore Formation of northwestern Colorado, and the Reagan Sandstone of the central midcontinent.

The Peerless Formation was defined by Behre (1932) as an upper member of the Sawatch for exposures on Peerless Mountain southeast of Leadville. The Peerless was raised to formation rank by Singewald (1947). Regionally, the Peerless varies in lithology and contains dolomitic sandstone, sandy dolomite, dolomite, and shale. The Peerless locally contains abundant

glauconite and often weathers to a reddish brown color. It is slightly less resistant to weathering than the Sawatch and forms variably persistent slopes and ledges. Anderson (1970) identified a basal red to brown cross-bedded sandstone, a medial unit of dolomitic sandstone and shale, and an upper unit of predominantly dolomite in the southern part of the Mosquito Range in central Colorado. Maher (1950) included about 15 m (50 ft) of sandstone and dolomitic sandstone at Manitou Springs within the Sawatch and the overlying 5 m (15 ft) into the Ute Pass Dolomite (a Peerless equivalent). We tentatively include the upper 11 m (35 ft) of Maher's sequence in the Peerless.

The upper contact of the Peerless may be difficult to define locally. At Williams Canyon, an approximately 4.6 m (15 ft) transitional unit of interbedded dolomitic sandstones and wavy dolomite beds occurs between dolomite beds typical of the Ordovician Manitou and dolomitic sandstone beds typical of the Late Cambrian Peerless. The base of this transitional unit is sharp and can be traced for tens of feet along strike. McMillan and Myrow (1992) described a sharp disconformity at the top of their Peerless in Williams Canyon which represents the entire Trempealeauan (Upper Cambrian) and Gasconadian (lowermost Ordovician) Stages. Based on conversations with P.M. Myrow, the base of our transitional unit most likely represents the disconformity. Paleontologic data were not available in our study, and these transitional beds were tentatively placed in the Manitou.

The Peerless Formation is queried on the enclosed chart because of the uncertainty in picking the upper contact and because of the significant differences in lithology between the type section of the Peerless near Leadville, Colorado, and our measured sections in the Manitou Springs area.

Based on criteria used for this study, the Peerless Formation varies from approximately 8 to 15 m (25 to 50 ft) thick in the Manitou Springs area and includes lithofacies units C and D (see Lithofacies section below).

Measured Sections

The four measured sections and their stratigraphic correlations are presented here using the Stratigraphic Report Graphic (SRG). The SRG is a stratigraphic applications computer program developed by the U.S. Geological Survey and Petroleum Information Corporation of Denver, Colorado. The SRG records sedimentologic, paleontologic, lithologic, paleoecologic, and nomenclatural data for outcrop sections and cores, and displays these data in graphic form using a scale-variant format (Petroleum Information Corporation, 1984; Dyman and others, 1985). The SRG is proprietary to Petroleum Information Corporation, but it is available by contract to the U.S. Geological Survey.

Lithofacies

The rocks measured in these sections have been divided into five lithofacies that are consistent in lithology, but not strictly in thickness, from one outcrop to another. A brief description of each lithofacies and a preliminary interpretation of the depositional environments follows.

Unit A

Unit A consists of approximately 4.6 m (15 ft) of light-gray medium- to coarse-grained, arkosic to subarkosic, dominantly flat-bedded sandstone and conglomerate. Rare beds of rippled and cross-bedded sandstone are also present. The basal contact with Proterozoic granite is usually flat but may show relief of a meter or more. Individual beds fine upward from conglomeratic bases and form cm to m-scale fining-upward sequences. Trace

fossils occur on the undersides of several beds. Unit A forms the lower part of the Sawatch Quartzite.

The fining-upward and laterally persistent horizontal bedding suggests sheetflood deposits of braided streams. The occasional trace fossils, almost certainly marine in the Late Cambrian, suggest some marine influence. Our preliminary interpretation is a braid delta system (fan delta in the terminology of Nemec and Steel, 1988).

Unit B

Unit B is a 0.3 to 0.7 m (1 to 2.3 ft) -thick bed of medium- to coarse-grained, light-gray, arkosic to subarkosic, mottled sandstone. The strongly developed mottling is due to bioturbation. A sharp contact with the overlying unit (Unit C) shows signs of scour and is accentuated by a color contrast from light gray of Unit B to reddish brown and dark green of Unit C. Unit B forms the upper part of the Sawatch Quartzite.

Unit B is very similar to Unit A lithologically, but bedding is often obscured by bioturbation. Our preliminary interpretation for Unit B is a shallow marine environment where sediment deposited originally as part of Unit A was reworked by the biota.

Unit C

Unit C consists of about 3 to 7 m (10 to 23 ft) of poorly sorted, fine- to coarse-grained, reddish-brown to brownish-gray, glauconitic, dolomitic, and arkosic sandstone. Large, low- to moderately-dipping trough crossbed sets fill broad scours. These large crossbeds have superimposed wave-ripple laminae. Unit C forms the lower part of the Peerless Formation.

The contact between Unit B and Unit C represents a significant change in depositional environment, as shown by the sudden appearance of abundant glauconite. We interpret this to reflect a further increase of water depth on a marine shelf. The large crossbed sets are suggestive of tidal-channel environments.

Unit D

Unit C grades upward into Unit D, which consists of 8 to 14 m (26 to 46 ft) of moderately to well-sorted, fine- to medium-grained, bioturbated sandstone and siltstone. Sandstones are arkosic, glauconitic, and locally rippled. The unit contains some hummocky crossbeds. Unit D is similar to Unit C but is finer grained and does not contain large crossbed sets. Unit C forms the upper part of the Peerless Formation.

The compositional similarity between Units C and D and their gradational contact suggest a continued gradual water deepening and/or a more distal environment. We interpret Unit D as representative of low-energy subtidal marine shelf environments.

Unit E

Unit E includes transitional beds of the upper Peerless Shale and the lower part of the overlying Manitou Dolomite. The lowermost approximately 5 m (15 ft) includes interbedded dolomitic sandstone, sandy dolomite, and dolomite. Dolomite beds are thin and wavy and increase in abundance upward in the unit. Sandstone is fine- to coarse-grained and quartzose, arkosic, and locally glauconitic. Sandstone forms beds which range from a few centimeters to more than 0.5 m (1.6 ft) thick. Thinner sandstone beds are rippled. Dolomite beds contain algal laminations, bioherms, birdseye structures, solution-collapse breccias, and strongly burrowed bedding surfaces. Unit E forms outcrop surfaces which are medium to light gray.

Unit E includes many features of sediments deposited in shallow-water and sabkha environments. It thus shows a reversal of the transgressive

trend of Units A to D. These shallow to supratidal sediments may have been deposited either onshore or as part of an offshore bar system.

Locations of measured sections

Manitou Springs #1-- El Paso County, Colorado, SE SE section 31, T. 13 S., R. 67 W.

Manitou Springs #2--El Paso County, Colorado, SW SE section 31, T. 13 S., R. 67 W.

Williams Canyon #1--El Paso County, Colorado, SW section 32, T. 13 S., R. 67 W.

Cave of the Winds #1--El Paso County, Colorado, NE SE section 31, T. 13 S., R. 67 W.

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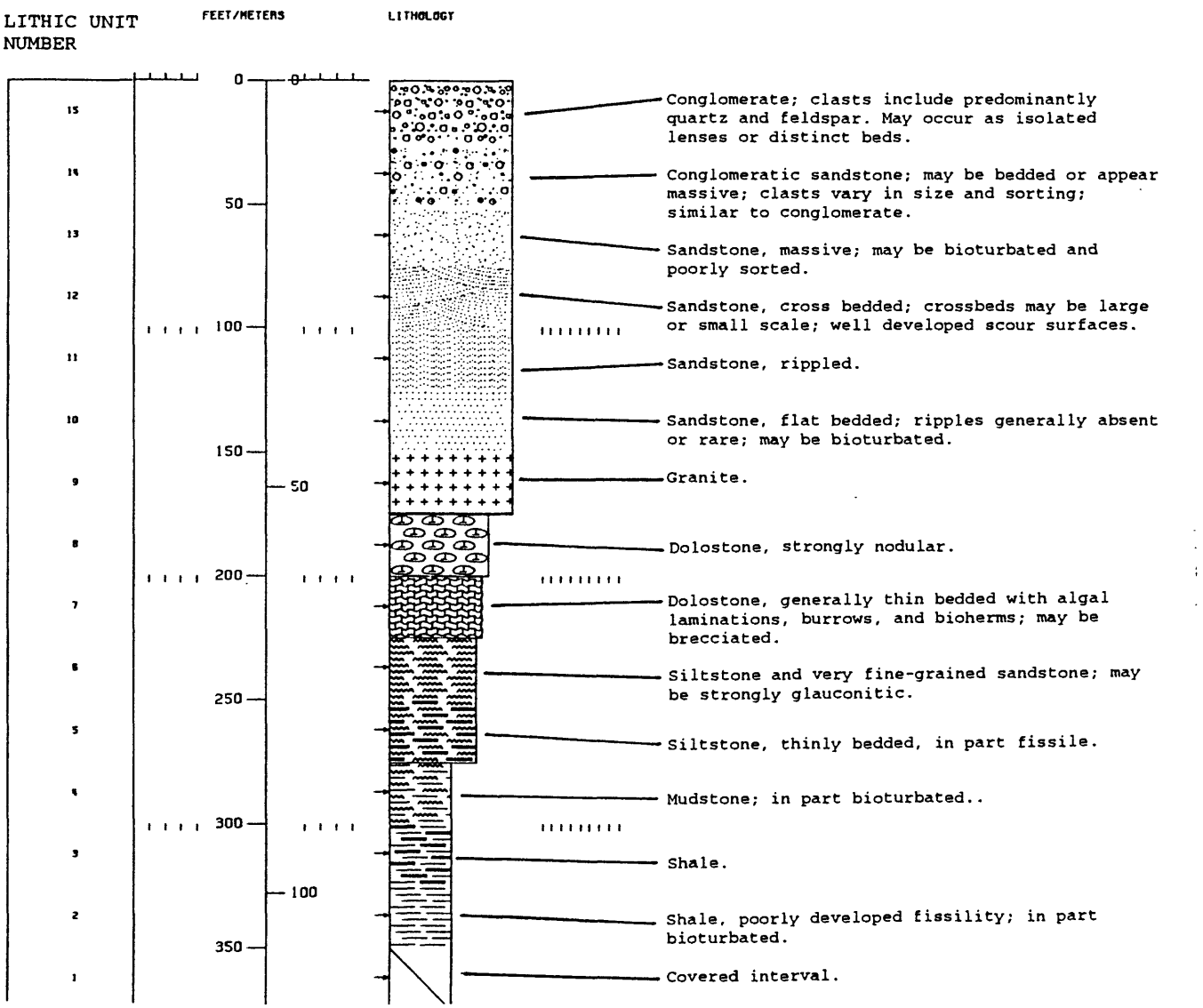
EXPLANATION OF STRATIGRAPHIC DATA SHOWN IN GRAPHIC SECTIONS

(A) Lithic unit number. The numbers are in sequence, with the highest number representing the youngest or uppermost unit. Some unit numbers are repeated reflecting subdivision of the unit subsequent to incorporation into computerized sections. Unit numbers to left of lithology column (C) correspond to numbered descriptions to right of column.

(B) Thickness (column labeled "feet/meters"). Each measured section is displayed as a vertical column in feet and meters. Data are presented at a vertical scale of 1 inch = 5 feet. Graphic resolution for individual beds at this scale is 0.25 feet (beds less than 0.25 feet thick are not displayed). Lithologic symbols represent the dominant lithology in the interval depicted.

(C) Lithology (graphic section). The legend shows lithologic symbols and an explanation of lithologies.

(D) Unit horizon. Arrows at left-most margin of each graphic section represent center of rock unit. Unnumbered arrows correspond to additional unit number in "lithic unit number" column.



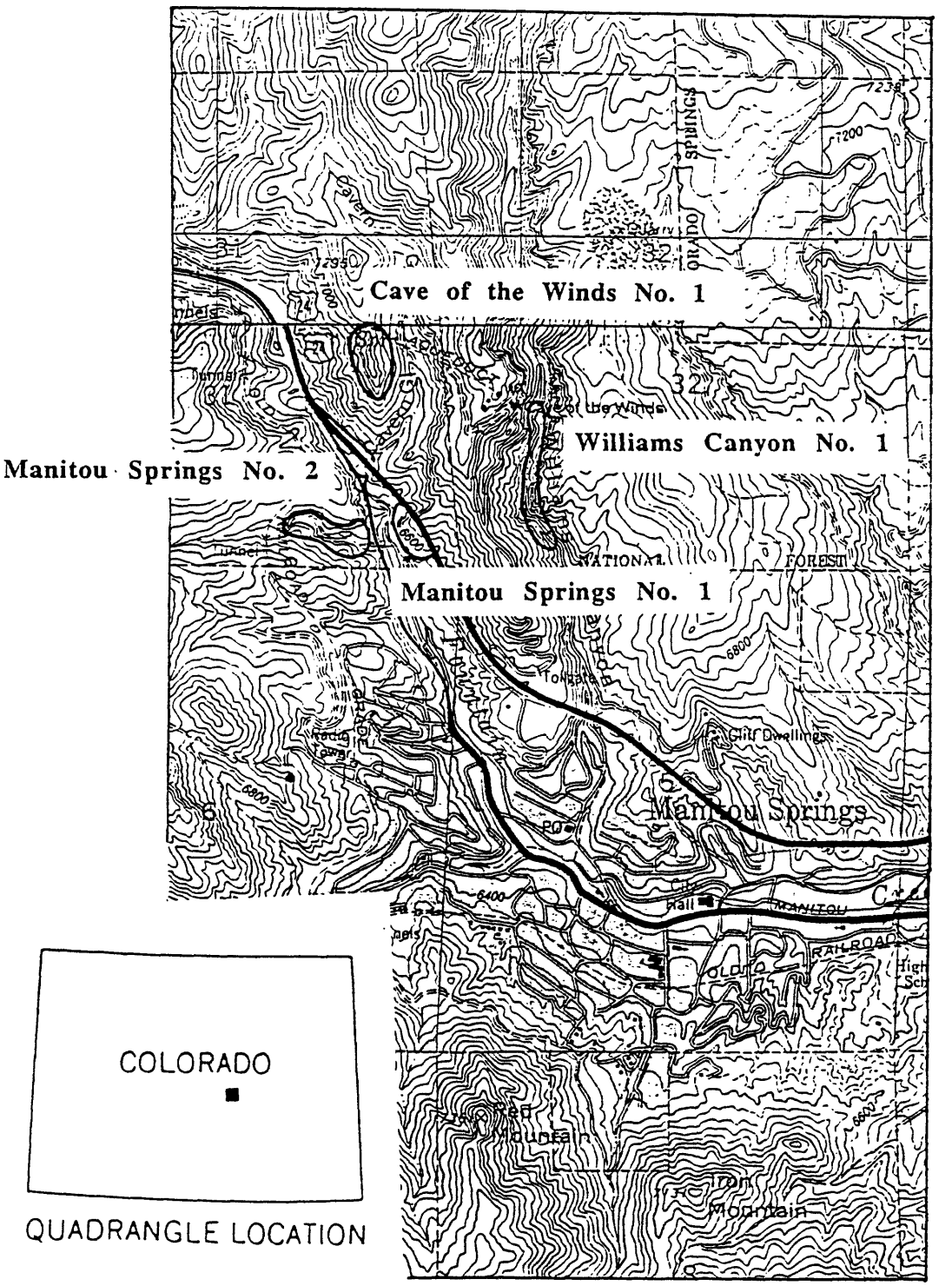


Figure 1. Map of study area showing locations of measured sections. Manitou Springs 7.5-minute quadrangle, Colorado. Areas enclosed by black lines represent locations of measured sections. Scale approximately 2.54 inches= 1 mile.