Depositional environments of the Cambrian Flathead Sandstone: Park County, Wyoming

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INRODUCTION

The Flathead Sandstone of Wyoming and Montana is a basal sandstone deposited during the earliest transgression of the Cambrian sea over the North American craton. The formation is Middle Cambrian in age, and unconformably overlies 2.7 Ga granitic basement rocks. Although most of the early literature emphasizes the marine influence and apparent maturity of the sandstone (Miller, 1936), work by Middleton (1980) reveals evidence of both marine and depositional realms. Previous studies have examined large scale regional variations on the Flathead Sandstone, but little detailed work has been done on a local scale. The purpose of my project is to resconstruct the local depositional processes during the first stages of Cambrian sedimentation using stratigraphic and petrographic analyses of the Flathead Sandstone in the Clarks Fork region of Wyoming.

GEOLOGIC SETTING

The Flathead Sandstone was deposited during the first stages of the Sauk transgression, a eustatic sea level rise during which much of the North American craton was drowned and buried in sediment (Lochman-Balk, 1972). The north-south trending shoreline began to advance eastward across the continent in the latest Proterozoic, reaching western Wyoming in the Middle Cambrian, and desspositing the Flathead Formation. As sea level continued to rise through the Cambrian, a series of deeper-water lithologies was deposited over the sandstone; these appear today as the Gros Ventre Shale, Pilgrim Limestone, and Snowy Range Formation.

METHODS

Outcrops of Flathead Sandstone at 7 locations in the Clarks Fork Valley were measured and described (Fig. 1). 48 samples of Flathead Sandstone and one sample of the underlying granite were point-counted for mineralogic composition using a modified Gazzi-Dickinson method (Cox and Lowe, 1996). 400 framework grains between 0.2mm and 0.7mm in diameter were counted in each sample. Lithic fragments containing sand-sized crystals were counted as dissagregated grains. Each thin section was also analysed for grain size and texture.

TEXTURE AND COMPOSITION

Samples of the Flathead Sandstone contain an average of 90% quartz. However, samples from certain outcrops contain up to 40% feldspar. The majority of the quartz is monocrystalline, with varying degrees of undulosity. Polycrystalline quartz (>3 crystals), stretched metamorphic quartz, and chert also are present in most samples. The dominant feldspar is twinned microcline, although certain samples contain an abundance of untwinned K-feldspar. All unstable lithic fragments are granitic. Accessory minerals include zircon and micas (mostly muscovite). Textures range from submature to very mature. Many samples contain a bimodal population.

PROVENANCE

Data were plotted on standard ternary diagrams (Dickinson and Suzcek, 1979) showing the relative amounts of quartz, feldspar, and lithic fragments. On a QFL plot, the average composition of the 48 samples plots in the craton interior zone, although several samples plot in the transistional continental and basement uplift zones (Fig. 2). These data are compatible with the cratonic location of the sandstone and the lack of tectonic activity during the Middle Cambrian. Samples with a higher feldspar content may reflect local relief on the basement rocks.

Evidence for a metamorphic source On a Q_mFL_t plot in which polycrystalline quartz and chert are included with lithics, more detail is revealed (Fig. 3). Although the average composition of all the samples still falls within the craton interior zone, 3 samples contain enough chert and metamorphic quartz to plot in the recycled orogenic zone. No local source for these rock fragments exists, but Belt Supergroup metasediments from the north, as well as granitic gniesses from the Beartooth Plateau, could have supplied metamorphic quartz (Middelton, 1980). Only resistant rock fragments are found, implying a distant source.

Origin of Feldspars The granitic provenance of the feldspathic sandstones is evident from Fig. 4, in which all samples plot on the Q-K join. Their composition is consistent with derivation from the underlying granite. A portion of untwinned feldspars could not be positively identified, and was counted as "undifferentiable," introducing possible bias into the interpretation. This is tested by including F_u on the QPK plot as shown in Fig.

7. A spectacular sackung formed by east-west gravitational spreading of Dead Indian Hill; the sandstone blocks feed a large talus and block slope.
8. After the large Clarks Fork outlet glacier had retreated from the area near the mouth of Beartooth Creek, the Crandall Creek valley glacier probably advanced far enough east to block Clarks Fork.
9. There is abundant evidence for catastrophic floods during retreat of the Clarks Fork outlet glacier; estimated paleodischarges at various water depths range from 7 to 43 x 10^3 m^3/sec.
10. A lineament along a segment of Lake Creek may be the result of late Quaternary reactivation of a fault mapped in Archean crystalline rock.
11. The sediments of Swamp Lake and the Corral Creek alluvial fan contain a record of postglacial processes; the organic horizons, including paleosols, have radiocarbon ages as old as 11,560 years B.P.
12. During the springs of 1995 and 1996 large mass-wasting events occurred on Cathedral Cliffs; the slumps and earthflows were the result of saturation of pre-existing colluvium lying on Cambrian shaley strata.

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Figure 1. Map of the Clarks Fork Region

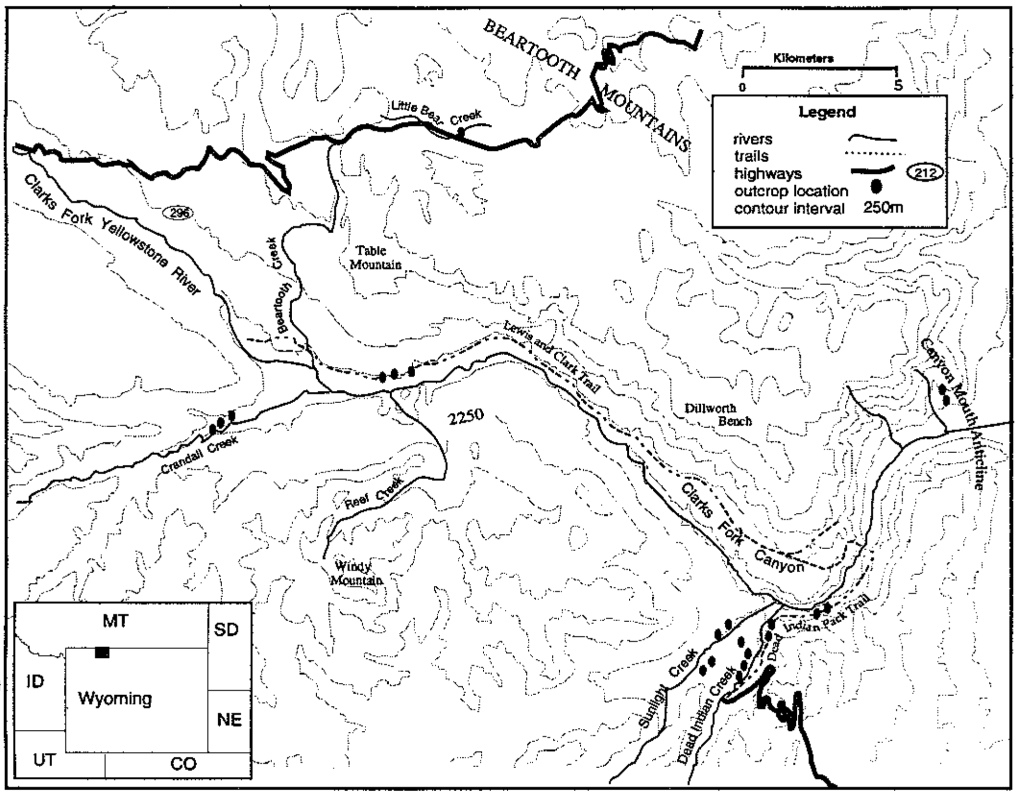

Figure 2. QFL diagram after Dickinson (1979)
Figure 3. QmFLt diagram after Dickinson (1979)
Figure 4. Modified QPK diagramafter Dickinson (1979)
Figure 5. Modified QPK diagrams including undifferentiated feldspars.

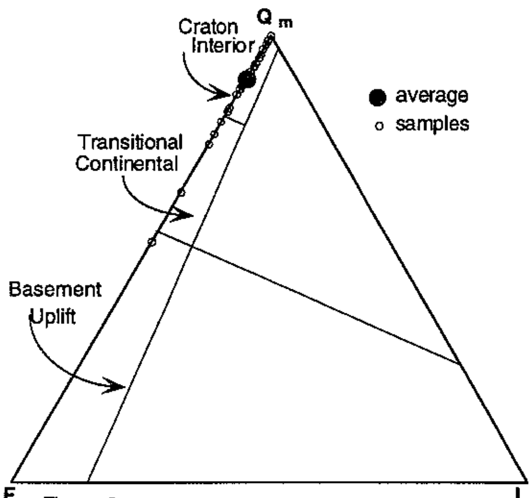

Figure 2.

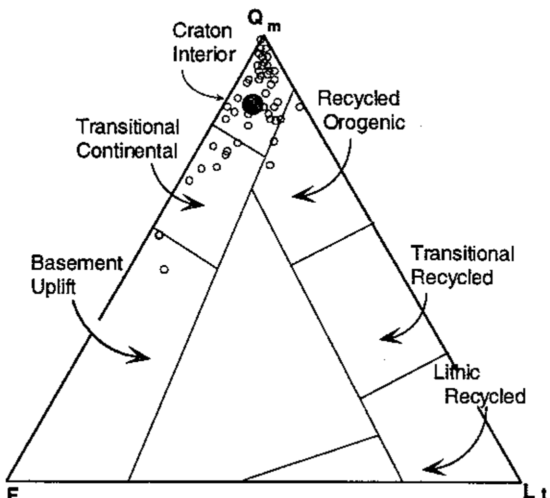

Figure 3.

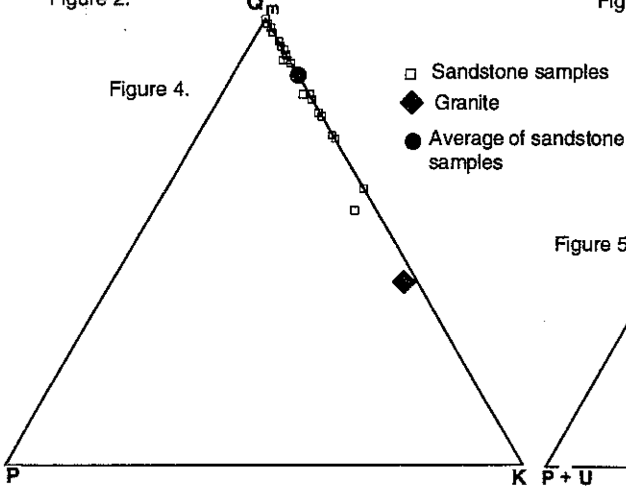

Figure 4.

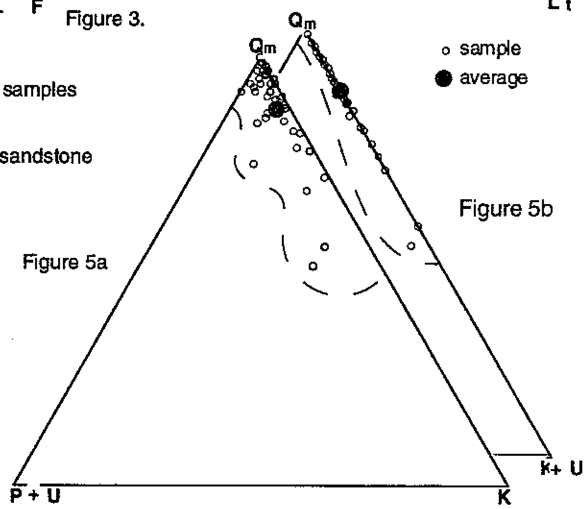

Figure 5a

Figure 5b

5. The possible end-member compositions are shown, where all F_u is counted as plagioclase (Fig. 5a) and where all F_u is counted as K-feldspar (Fig. 5b). Although the data show a greater spread when the undifferentiated feldspar is included with the plagioclase, the interpretation of the plot as indicating a feldspathic-granitic provenance is not altered.

SEDIMENTOLOGY

Lithology and structure A wide variety of sedimentary structures and textures exist in the Flathead Sandstone outcrops studied. Conglomerates appear at the base of the formation in several locations, although they are less than a meter thick and laterally discontinuous. Silty sandstone and shale occur in thin, discontinuous beds in most of the outcrops studied, but make up a very minor amount of the formation. The majority of the sandstone is medium grained (between 0.2 and 0.7mm in diameter) and distinctly bedded. Thin horizontal bedding, low-angle cross bedding, and trough cross-bedding are the most common structures.

Biogenic Structures Feeding traces on exposed bedding planes and vertical burrows occur along Sunlight Creek, Little Bear Creek, Crandall Creek, and east of Dead Indian Creek (Fig. 1). Feeding traces are associated with fine-grained beds, whereas vertical burrows occur in medium to coarse-grained beds. Both varieties suggest deposition in shallow marine environments.

Regional variation The architecture of the formation varies across the study area. In the north, lithology and grain size are more variable, and average grain size is larger. Outcrops in the south are generally better-sorted and over 90% quartz. Figures 6 and 7 show representative measured sections from the northernmost outcrop on the Beartooth Plateau (fig. 6) and the southernmost between Dead Indian and Sunlight Creeks (Fig. 7).

Depositional environments Middleton (1980) proposed a depositional model for the Flathead Sandstone including both marine and continental facies. Results of this study support this interpretation in the Clarks Fork region.

Regionally, the least mature portion of the Flathead Sandstone (conglomeratic and feldspathic sandstone) is interpreted as fluvially deposited. (Middleton, 1980). Sections measured at Little Bear Creek, Crandall Creek, along the Lewis and Clark trail, and the basal portions of sections measured between Sunlight Canyon and Dead Indian Creek and on the east side of Dead Indian Creek (Fig. 1) contain the least mature sandstone and conglomerate facies. In the study are, the deposits are poorly sorted, reflecting the variable energy of a fluvial system. Features consistent with a braided fluvial interpretation for this portion of the Flathead Sandstone include the presence fo pebble beds, absence of fine material, and a bimodal distribution of well-rounded, long travelled grains and large, angular unstable grains. Massive, poorly -sorted conglomeratic beds and channel fill structures are associated with flat-bedded medium sands and thin, gravelly interbeds.

Facies of the sandstone that are well-sorted, have a high quartz content, medium to coarse grain size, and mature texture show a greater degree of reworking and have been interpreted as beach and nearshore deposits. Facies containing thick beds and trough and planar cross-stratification may represent migrting sand-waves. (Middleton, 1980). The majority of the sections measured near Dead Indian and Sunlight Creeks and east of Dead Indian Creek, and the upper portions of sections measured near Little Bear Creek and Crandall Creek contain features indicative of a marine influence. These facies are medium-grained, texturally mature, and contain over 90% quartz. Most bedding is planar, horizontal to low-angle cross-stratified, although hummocky cross-stratification, dune cross-bedding and trough cross-bedding occur in some areas. Horizontal feeding traces on exposed bedding planes near Crandall, Dead Indian, and Little Bear Creeks suggest that these facies were deposited near the shoreline. The abundance of vertical burrows near Sunlight and Dead Indian Creeks indicates that these deposits were shallow marine.

In summary, the Flathead Sandstone in the Clarks Fork region of Wyoming represents the interface between terriginous and marine depositional environments during the first stages of Cambrian transgression. The composition of the sandstone is consistent with derivation from the underlying granite with a contribution from a distant metamorphioc source.

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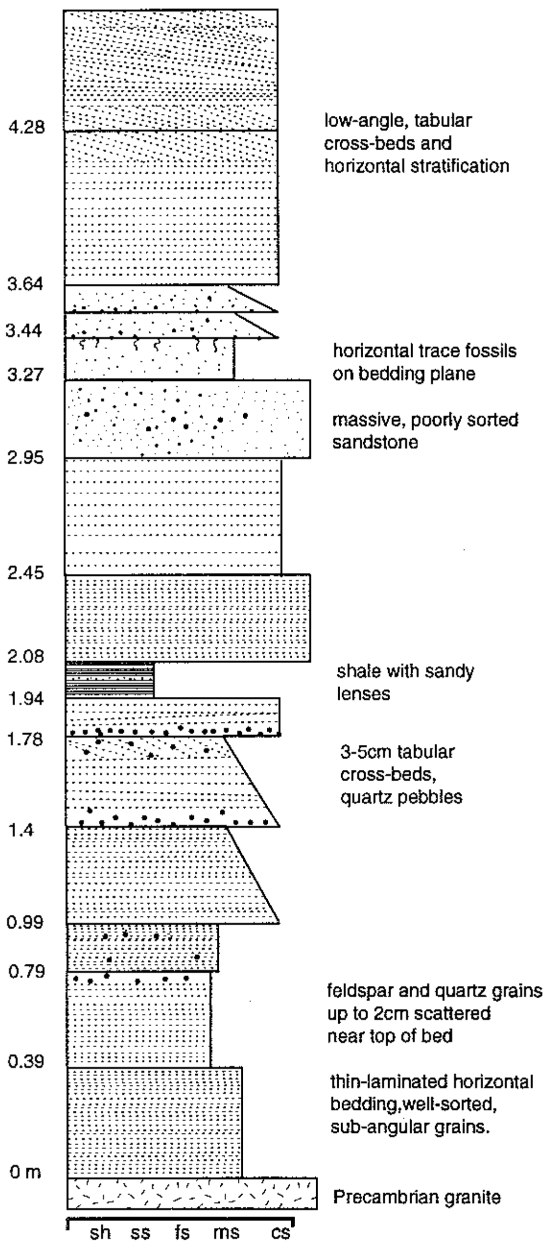

Figure 6. representative column from Little Bear Creek

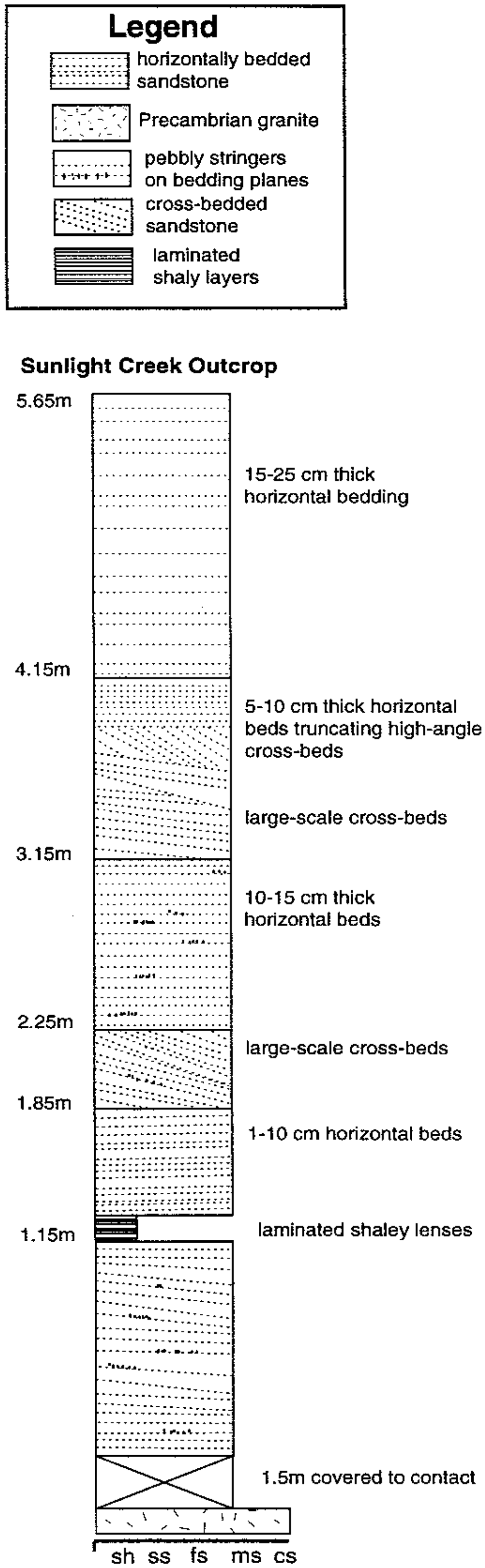

Figure 7. Representative column from Sunlight Creek

Depositional environments and diagenetic histories of Cambrian limestones, Clarks Fork River Valley, Wyoming

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INTRODUCTION

The Meagher Limestone and the Pilgrim Limestone, of Mid- and Upper Cambrian age respectively, were deposited as shallow-shelf, carbonate facies during the eastward transgression of the Cambrian Cordilleran sea across the continent of Laurentia. The two units are separated by the interbedded green shales and mudstones of the Park Shale. The purpose of this study is to determine the environments that formed the Meagher and the Pilgrim and to unravel their diagenetic sequences.

METHODS

Field Methods. I measured and sampled three sections of both the Meagher and the Pilgrim. Samples were taken from representative beds and at regular intervals vertically along the section. I made observations about the color of weathered and fresh surfaces, texture, grains, and the presence or absence of fossils and sedimentary structures.

Laboratory Methods. From the seventy-eight samples I collected, I made 146 thin sections for petrographic and cathodoluminescent analysis. I stained 52 of these thin sections with potassium ferricyanide and alizarin red sulphonate to distinguish between different types of carbonate minerals.

PETROGRAPHIC RESULTS

Meagher Limestone. The main grain types are trilobite bioclasts and other assorted fragments, which are very thin, small, and curved. In samples taken from Dead Indian Hill, the lower beds of the Meagher have numerous oncoids. The filaments that make up these grains are thin, tubular strands that create a twisted, woven mass. The layers that contain the oncoids also have a significant amount of anhedral quartz and feldspar and large, round glauconite grains. The matrix is primarily micrite mixed with coarser calcspar. The micrite has been infused with dolomite, which is present as small, anhedral crystals within the matrix or as clusters of coarse, euhedral rhombs along fractures. Also present in the matrix are burrow traces that are filled with coarse calcspar. Calcite crystals are found as infill in the burrows or as shelter fabric under oncoids. Prominent, crenulated stylolites and smaller pressure solution seams are common throughout the Meagher.

Pilgrim Limestone. The majority of grains in the Pilgrim are ooids and fossil fragments. Of these fragments, trilobites are the ones that can be easily recognized. Secondary grain types include intraclasts, quartz, feldspar, and glauconite. There are four types of ooids within the Pilgrim: radial, concentric, radial-concentric, and sparry. Radial ooids have fibrous crystals that radiate outward from the nucleus; this structure manifests itself as an extinction cross. Inside concentric ooids, the individual rings composing the grain are visible. A radial-concentric ooid is a combination of these two: both the radiating crystals and concentric rings are apparent, and an extinction cross is present. Sparry ooids show none of these structures; they are composed of several crystals of calcspar or one equant crystal. These ooids tend to be made of ferroan calcite while the other types of ooids are non-ferroan. Quartz grains come in a wide variety of shapes and sizes, from large, well-rounded grains to tiny, anhedral ones. Feldspar grains are small and angular; glauconites, while large or small, are round. The intraclasts are usually very large, elongated ovals oriented parallel to each other. These intraclasts are what make up the flat-pebble conglomerates; their composition and form are much more evident in hand sample or in the field.

Cement in the Pilgrim is mainly calcspar of many different sizes. A single thin section may contain enormous, anhedral crystals, small subhedral ones, and fine micrite. Many of the larger crystals are twinned. The calcite is generally non-ferroan, although ferroan cement is present in scattered places in most of the thin sections. Dolomite is the other prominent cement. As in the Meagher, the dolomite forms both anhedral microdolomite and coarse euhedral rhombs. Microdolomite tends to form in dense patches in intergranular spaces while the rhombs cluster along fractures.