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.

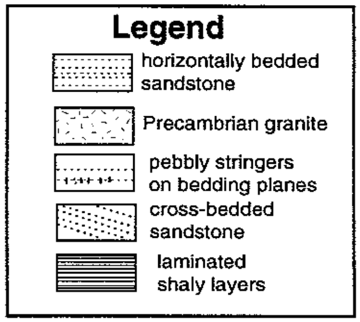
Laboratory Methods. From the seventy-eight samples I collected, I made 146 thin sections for petrographic and cathodoluminescent analysis. I stained 52 of these thin sections with potassium ferricyanide and alizarin red sulphonate to distinguish between different types of carbonate minerals.

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.



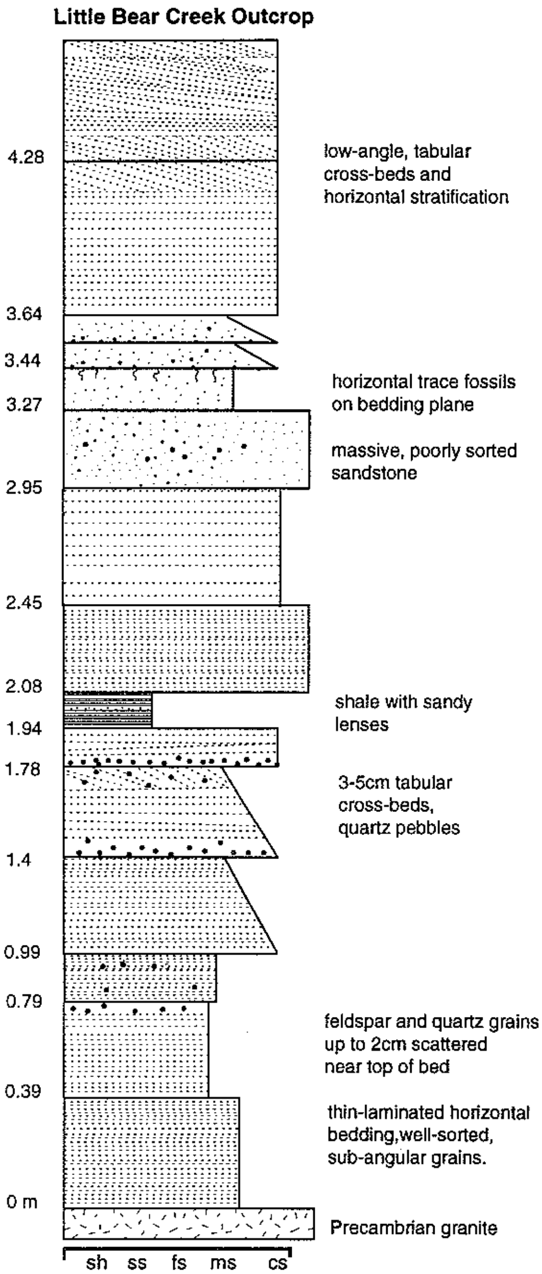


Figure 6. representative column from Little Bear Creek

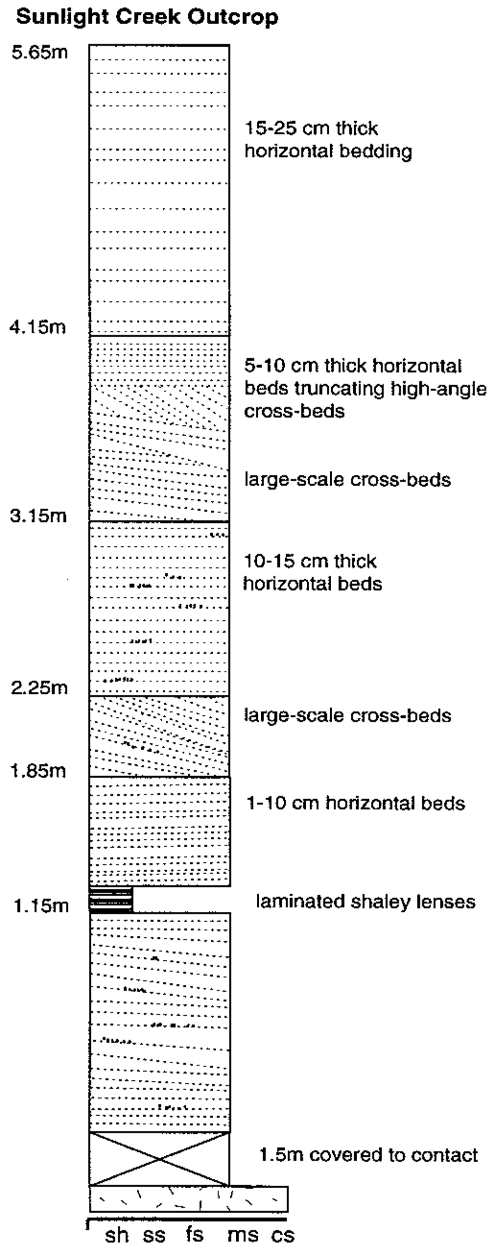
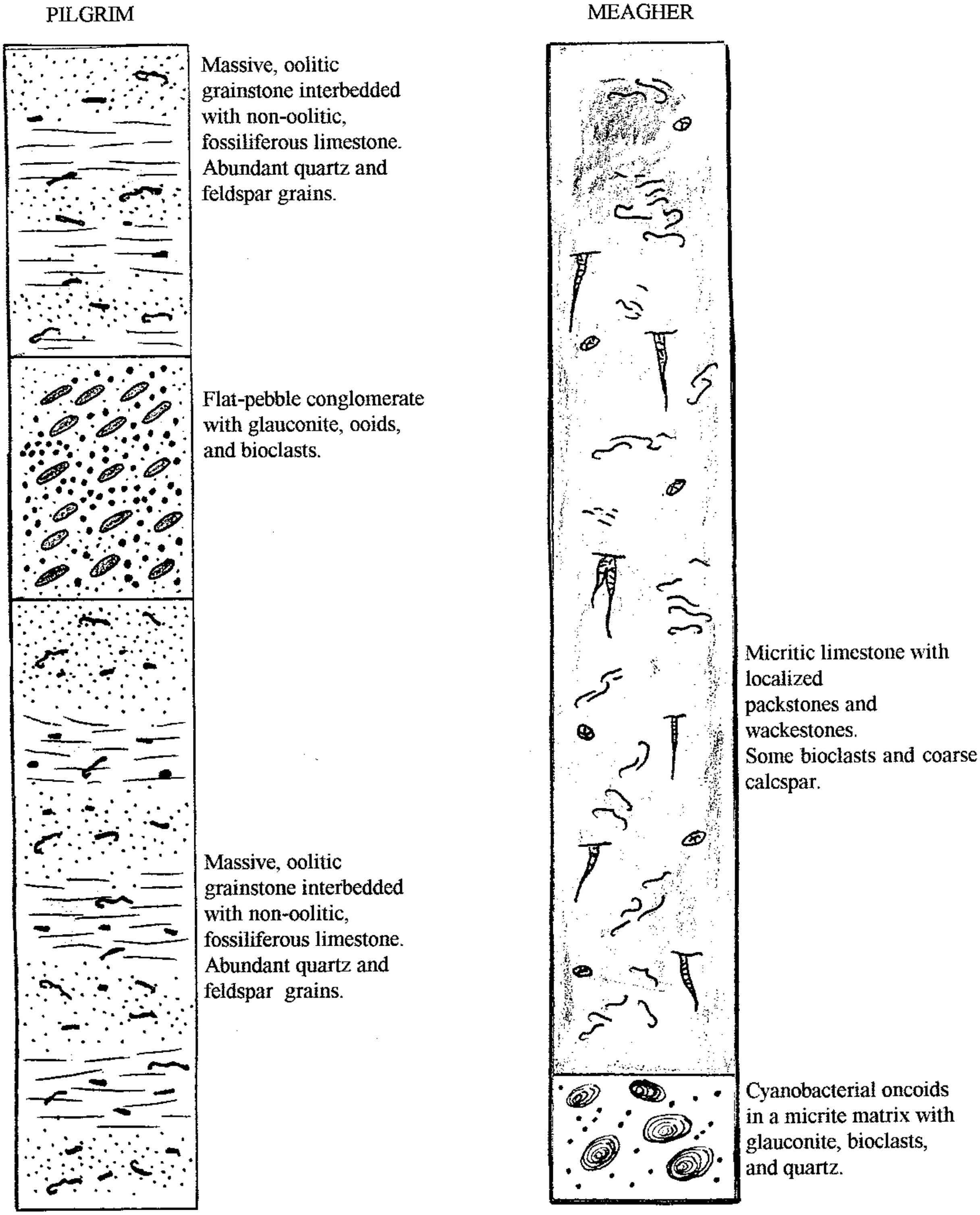


Figure 7. Representative column from Sunlight Creek



Scale: 1 cm = 1 m

Figure 1. Generalized stratigraphic columns of the Meagher and Pilgrim limestones compiled from field observations.

CATHODOLUMINESCENCE RESULTS

When thin sections are placed in a vacuum and bombarded with electrons, certain minerals will glow in a variety of colors. The color of calcite luminescence is generally varying degrees of orange or yellow. Potassium feldspar glows blue while quartz is dark purple, and glauconite is black.

The matrix and oncoids of the Meagher luminesce a strong orange. Most of the coarse calcspar is a dark brownish-orange; however, some crystals have a brighter orange color. Dolomite is a dark red, quartz dark purple, K-spar blue, and glauconite black. Bioclasts shine a dull brownish-orange. Thin sections of the Pilgrim luminesce a dark brownish-orange with slight variations in intensity within ooids and some of the calcite cement. The rings of concentric ooids glow brighter than the surrounding matrix, and most of the ooids' outer rims are more of a dull orange. In most of the thin sections, dolomite luminesces a dark maroon. Several thin sections' large euhedral dolomite rhombs have bright rims and maroon interiors. The quartz grains are dark purple, and the feldspars stand out with their blue glow. A few thin sections have fractures within them, and these cracks were filled with very bright orange calcite.

DEPOSITIONAL ENVIRONMENTS

Meagher Limestone. The oncoids that are in the Meagher are important indicators of water conditions at the time of formation. Oncoids are circular or ellipsoid grains formed by small, delicate filamentous cyanobacteria that accrete concentrically around a nucleus. In order for them to successfully grow, the water must be calm and quiet although gentle movement could be tolerated and would allow the cyanobacteria to grow evenly. Micrite composes nearly all of the matrix and shows no stratification of any kind. Instead, it is uniform in texture and appearance, which is a hallmark of heavy bioturbation. Additionally, there are areas of coarse calcspar that have filled in rounded burrow traces left by burrowing organisms, another indication of bioturbation. The churning of sediment is an activity that takes place in calm-water, low-energy environments because burrowing organisms prefer to live within a stable substrate. Bioclasts in the Meagher are very thin and fragile, yet have not been smashed into fossil hash. The energy of the water must have been low to allow this to happen. Therefore, the environment of deposition of the Meagher was in a quiet, low-energy, shallow subtidal zone, or in a back-barrier, lagoonal setting.

Pilgrim Limestone. The Pilgrim formed in a high-energy depositional environment. Primarily, the presence and abundance of ooids show this. Ooids form in areas where the water agitation is intense, which rolls the grain steadily and allows the calcium carbonate to grow into a sphere. Concentric ooids, especially, are products of high-energy environments. Crystals that begin growing radially are put under stress by constant abrasion caused by water movement. In response, the crystals break and flatten themselves closely around the nucleus (Simone, 1981). Additionally, the bioclasts in the Pilgrim are very thick and fragmented; in some areas they form a dense "fossil hash." This texture is easily and readily created in a turbulent, high-energy environment with intense wave action. The intraclasts that compose the pebble conglomerate are large, round, flat, and smooth when viewed in hand sample. This rock formed when thin layers of already-lithified sediments were ripped up during periods of high energy, such as storms. The loose pieces were shaped and rounded by water and were redeposited in the flat-pebble conglomerate. In the field, these pebbles appear imbricated, which is further evidence for the energy of the water. Thus, the depositional environment of the Pilgrim was in the high-energy, intertidal zone, where the action of waves and currents strongly affect formation and deposition of grains. An ooid shoal fits this description: situated in very shallow water, vulnerable to daily wave movement and storm action.

Presence of quartz and glauconite. The abundance of quartz in both the Meagher and the Pilgrim suggests that a stable continental body was nearby and provided periodic influxes of eroded siliciclastic material. The larger, more rounded quartz grains indicate fluvial transport over great distances, with the river mouth being close to where the limestone was being deposited. Thin sections with mainly small, angular grains probably did not have a river outlet close to where they were deposited; the larger material would have settled out first as the smaller grains continued to drift downcurrent until they settled. The glauconite is more difficult to interpret. It forms as pellets at the sediment-water interface, and in tropical environments the minimum depth of formation increases to 100 m (Velde, 1985). Glauconite formation depends on factors such as the chemical composition of the water, availability of organic material, temperature, and pressure. However, Chafetz (1996) has proposed that Cambrian glauconite pellets formed in shallow, subtidal zones, which is a departure from conventional theories.

DIAGENETIC HISTORIES

The cements that form within limestones are a product of specific environmental zones: saltwater or freshwater, vadose or phreatic. A signature of the phreatic zone, where all pores are saturated with water, is a complete filling of all available space with cements. The Meagher and the Pilgrim both exhibit this texture; all grain surfaces and pores contain calcspar. Blocky, coarse, or equant calcspar is precipitated in the freshwater zone. My limestones contain nothing but this type of cement. Therefore, the Meagher and the Pilgrim were cemented primarily in the freshwater phreatic zone. This area is complex and can be further subdivided depending on depth and saturation with calcium carbonate (Longman, 1980). The Pilgrim exhibits characteristics of the active circulation zone, where calcite forms rapidly into a dense, interlocking mass which coarsens towards the center of pores.

The extensive dolomitization suggests a period of deep burial which allowed the formation of large rhombs. Deep burial would also have created the many pressure solution seams and stylolites that run through the rocks. Once these cracks appeared, they allowed dolomitizing fluid to work its way deep into the rock and spread in all directions. Evidence of burial also come from the cathodoluminescence of the rock. As a rock enters increasingly more reducing environments, ferrous iron begins to act as a luminescence quencher, and gradually calcite grows less and less luminescent (Machel et al., 1991). Rocks from the Meagher have bright orange color, which means they were shallowly buried in mildly reducing environments where manganese acted as a luminescence activator. Anhedral calcspar that has dull luminescence formed during periods of deeper burial and more reducing conditions. The rocks of the Pilgrim have dark luminescence, which shows that they were buried quickly and the manganese could not activate.

CONCLUSIONS

Meagher Limestone. The Meagher was deposited in a stable, calm, low-energy environment such as the shallow subtidal or lagoonal zone. Evidence for this comes from the grains and texture of the rock. Oncoids found in the Meagher form by the growth of filamentous cyanobacteria around a nucleus, an activity that takes place in a low-energy environment. The Meagher has been heavily bioturbated by burrowing animals; their traces show as holes and passages in the matrix, and have been filled with calcspar. Bioturbation is common in areas of low energy where the substrate remains stable. The Meagher was cemented within the freshwater phreatic zone, and this is shown by the abundance of blocky calcspar that has covered every available surface. A period of deeper burial is indicated by a number of stylolites and pressure solution seams, which have allowed extensive dolomitization of the rock. Evidence for burial also comes from the cathodoluminescence of the rock, where bright orange is mixed with dull brown, showing progress through different burial depths.

Pilgrim Limestone. The Pilgrim was deposited in an active, high-energy environment, such as an ooid shoal that lay within the intertidal zone. Ooids form easily in this area because the constant wave motion lets aragonite precipitate evenly and concentrically around a nucleus. The smashed-up, fragmented bioclasts also attest to the energy of the water within this zone. Flat-pebble conglomerate is formed by intense storm action ripping up pieces of rock, reshaping, and redepositing them. The wide variety of quartz grains indicates the presence of a nearby continent and fluvial transport of siliciclastic sediments. The Pilgrim was cemented in the freshwater phreatic zone, which is shown by the isopachus, blocky calcite spar. The Pilgrim was buried deeply; evidence for this comes from the dull, dark cathodo- luminescence of the rock.

REFERENCES

1. Chafetz, H.S., 1996, Syndepositional, shallow-water precipitation of glauconite: the present is not the key to the past: Geological Society of America Abstracts with Programs, v. 28, no. 7, p. A-275.
2. Longman, M. W., 1980, Carbonate diagenetic textures from nearsurface diagenetic environments: American Association of Petroleum Geologists Bulletin, v. 64, no. 4, p. 461-487.
3. Machel, H.G., Mason, R.A., Mariano, A.N., and Mucci, A., 1991, Causes and emission of luminescence in calcite and dolomite, *in* Barker, C.E., and Kopp, O.C., eds., Luminescence microscopy and spectroscopy: qualitative and quantitative applications: Society for Sedimentary Geology, p. 9-25.
4. Simone, L., 1981, Ooids: a review: Earth-Science Reviews, v. 16, p. 319-355.
5. Velde, B, 1985, Clay minerals: a physico-chemical explanation of their occurrence: Amsterdam, Elsevier Science Publishers, 427 p.

The origin of flat-pebble conglomerates in the Upper Cambrian of the Clarks Fork region, Park County, Wyoming

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INTRODUCTION

In the Yellowstone area of northwest Wyoming where the Clarks Fork region is located, flat limestone pebble conglomerates are found in the upper Pilgrim Limestone and the lower Snowy Range Formation of the Upper Cambrian. Ruppel (1972) described the Pilgrim as including three main lithologic units: (1) a lower unit of interbedded ribboned limestone, oolitic limestone, and less common flat limestone pebble conglomerate and shale; (2) a middle unit of limestone pebble conglomerate; and (3) an upper unit of mottled oolitic limestone. The Snowy Range Formation conformably overlies the Pilgrim Limestone and is divided into the Dry Creek, Sage, and Grove Creek Members.

The general term "conglomerate" refers to poorly-sorted coarse-grained sedimentary rock. In the case of flat-pebble conglomerates found in the Clarks Fork region, the grains range from large sub-rounded to rounded limestone pebbles down to the silt-sized grains in a sparry limestone matrix. The pebbles tend to have a "flat" appearance in that their width/length is much greater than their thickness/height.

Conglomerates can be divided into two categories: intraformational and extraformational. Flat-pebble conglomerates are intraformational conglomerates because they are composed of clasts which are derived from within the basin of deposition; the clasts are not from a different source outside that environment as is, for example, conglomerate found in a river bed (Tucker, 1991). Intraformational limestone conglomerates composed of rounded, tabular intraclasts are also referred to as calcirudites. These conglomerates are common in shallow-water carbonate facies throughout the geologic column but are especially abundant in early Paleozoic strata. Younger carbonate facies contain much fewer flat-pebble conglomerates, indicating a very uneven distribution of this rock type through geologic time (Sepkoski, 1982).

Geologists have been studying, mapping, and publishing works on the area of northwest Wyoming for over 100 years. However, few geologists have concentrated on research addressing the Cambrian flat-pebble conglomerates. Brett, Liddell, and Derstler (1983) studied Late Cambrian hard substrate communities which were found encrusting the upper surfaces of flat-pebble conglomerates in the Snowy Range Formation. I visited one of their site locations in order to compare their observations to my own. Flat-pebble conglomerates have been studied more extensively in other locations around the world, but there are still several questions which remain to be answered.

The purpose of this project is to investigate the origin of flat-pebble conglomerates and the pebbles that compose them. Specifically, I have developed hypotheses for the formation mechanisms of the pebbles, why they are flat and rounded, how they were deposited, and how they were lithified and cemented to form a conglomerate hardground.

METHODS

Field Methods. Flat-pebble conglomerate beds were examined at ten different sites including roadcuts and outcrops. Field work included observations, measurements, and descriptions of flat-pebble conglomerate and surrounding beds, collecting samples of various forms of the conglomerate, and taking photographs to illustrate certain features.

Laboratory Methods. Acetate peels and thin sections were made from samples collected in the field.

FIELD OBSERVATIONS

Flat-pebble conglomerate is preserved in beds ranging from 4 to 46 cm thick in the Pilgrim Limestone and 7 to 58 cm thick in the Snowy Range Formation. The pebble clasts are rounded to sub-rounded, sometimes having a globular appearance, and are characteristically flat. The size of the pebble clasts can range drastically within a single bed, but usually they measure a few centimeters in length when viewed in cross section. The smaller pebbles are only a couple millimeters long while the largest pebbles are more than 15 cm long, with the longest clast recorded as 29 cm long. The density of pebbles in the conglomerate varies from sparse to densely packed. Their