The name Belden shale has the advantage of having been widely accepted in recent years and of being ungarbled by redefinitions. The new name, Minturn formation, is applied in preference to older names because none of the old names seems usable, particularly since Maroon is being used for the upper formation. Weber, or Weber(?), has long been regarded unsatisfactory. Battle Mountain, introduced by Brill[49] in 1942, was in effect abandoned by him in 1944, when he proposed use of the term Maroon for the same beds; and Battle Mountain as defined does not correspond to the divisions here recognized. McCoy was applied to the lower half of the Pennsylvanian and Permian(?) section in the McCoy-State Bridge area,[50] which is isolated from the main exposures of Pennsylvanian rocks by a ring of younger rocks, but this division corresponds to no natural division recognizable elsewhere. The Belden facies is absent at McCoy, but Basset[51] correlated the McCoy with beds near Dotsero which are now recognized as Belden.

Although the name Maroon formation has been used in many different ways, as indicated above and in table 2, it is so old and widely known a term that its retention seems desirable. Moreover, the proposed usage differs from recent usage of the Geological Survey[52] only in that the base is now placed at a definite horizon a little higher in the section. Other names have been applied to the rocks here called Maroon formation, but they do not seem applicable in the southern Gore and Mosquito Ranges. "Wyoming" has long been abandoned. State Bridge has been applied to a siltstone facies that is not recognized in the Minturn-Pando-Kokomo-Leadville region, or in the Glenwood Springs region; and Brill evidently experienced difficulty in distinguishing this unit from his Maroon formation southeast of Glenwood

---

[49]Brill, K. G., op. cit. (1942), p. 1379.

[50]McCoy was recently extended by Donner to include all but the top 525 feet of the section. See footnote 44.

[51]Basset, C. F., Paleozoic section in the vicinity of Dotsero, Colorado: Geol. Soc. America Bull., vol. 50, pp. 1861-1863, 1939.

[52]Wilmarth, M. G., Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, pt. 2, p. 1307, 1938.

Springs.[53] Use of a new name for the formation was also considered, but as such a name would be used only in the eastern part of the Pennsylvanian and Permian(?) basin of west-central Colorado, whereas Maroon probably could be used for approximately equivalent beds in the western part also, Maroon is more desirable.[54]

The Minturn formation comprises about 6,000 feet of clastic rocks overlying the Belden shale. It consists chiefly of grit, is predominantly gray except for redbeds at the top, and is known to be of middle Pennsylvanian (Des Moines) age to within 1,000 feet of the top. The top of the formation is placed at the top of a member known as the Jacque Mountain limestone. The Minturn formation is overlain by at least 2,000 feet of unfossiliferous upper Paleozoic redbeds, to which the name Maroon formation is here applied.

Pennsylvanian Series

Belden shale

Following the usage of Brill,[55] the term Belden shale is applied to the dark Pennsylvanian shales and limestones unconformably overlying the Leadville dolomite—the beds formerly called the Weber(?) shale. The Belden consists principally of dark carbonaceous shale and thin beds of dark-gray to black limestone. It contains a few beds of dark sandstone and a few thin beds of white quartzite, particularly at the base and near the top. Thin seams of coaly material occur in the black shale at places, and locally the shale contains a little dirty brown gypsum or anhydrite in lenses a fraction of an inch to a few inches thick. A section of the Belden shale is given with sections of the Minturn formation on page 228.

---

[53] Brill, K. G., op. cit. (1944), p. 636.

[54] By direction of the Committee on Geologic Names on August 20, 1949, the term Maroon will be used by the U. S. Geological Survey in eastern part of the Pennsylvanian and Permian(?) basin of west-central Colorado as used herein, and it will be applied also to the redbeds overlying the gypsum in the central and western parts of the basin (see Bass, N. W., and Northrup, Stuart, South Canyon Creek tongue of the Phosphoria formation near Glenwood Springs, Colorado. Manuscript in preparation).

[55] Brill, K. G., op. cit. (1942), p. 1385.

The Belden lies on an uneven erosion surface on the Leadville dolomite. At most places in the upper Eagle River area, this surface is merely wavy and has a relief of only a few feet, but it is scarred locally by deeper channels and irregular depressions, and by a few sink-holes, some of which can be observed to connect with the caves and smaller openings of an ancient underground channel system. Although the upper foot or two of the Leadville dolomite shows some evidence of pre-Belden weathering, it is typically firm and unbroken, and at most places the basal bed of the Belden lies on a smooth surface of dolomite, with no intervening layer of ancient soil or regolith. Locally, however, depressions in the top of the dolomite are filled with a red, yellow, or brown mixture of clay and chert fragments, as described on a preceding page, and at a few places such material forms veins or a filling around residual boulders or blocks of Leadville dolomite. This Molas-type material is less than five feet thick at most places, and it has been mapped as part of the Belden shale.

The Belden grades upward into the overlying Minturn formation, the basal part of which consists of quartzite or grit in beds 2 or 3 feet thick and interbedded greenish or brownish micaceous shale, with minor black shale and limestone of the Belden type. The top of the Belden is drawn rather arbitrarily at the place where quartzite and micaceous shale begin to predominate over black shale and limestone. At most places this horizon is at the base of the first two- or three-foot quartzite beds. The Belden is about 125 feet thick at most places along the Eagle River near Pando, but it thins to the east and northeast, as is well shown by Brill's isopach map,[56] and it is probably absent beneath the northeastern part of the Pando area.

Some of the dark limy shale beds in the Belden contain abundant fossils, particularly brachiopods and pelecypods, and many of the limestones are crowded with minute ostracods. Brill[57] has assigned a Cherokee age to the Belden.

[56]Brill, K. G., op. cit. (1944), p. 626.
[57]Brill, K. G., op. cit. (1944), p. 626.

CARBONIFEROUS AND PERMIAN(?) SYSTEMS

PENNSYLVANIAN SERIES AND PERMIAN(?)

Minturn formation

A series of clastic rocks about 6,000 feet thick lying between the Belden shale and the Maroon formation is here designated the Minturn formation. The formation is named for extensive exposures of these rocks in cliffs along the east side of Eagle Valley near Minturn. It is made up of lenticular beds of arkosic grit, shale, conglomerate, sandstone, and quartzite, and a few relatively persistent beds of dolomite and limestone. Most of the formation is grayish in color, although many of the rocks are pale shades of pink, green, or yellow. Maroon-colored rocks occur in a relatively thin and irregular zone in the lower part of the formation and near the top. The lower zone of reddish rocks shows considerable range in thickness and in stratigraphic position. Near Minturn and Gilman it is 100 to 300 feet thick and lies 200 to 400 feet above the Belden; near Pando the zone is 500 feet thick and lies 500 feet above the Belden. The lowest red beds in the upper part of the section are about 1,800 feet below the top of the Minturn formation. From this level upward for about 900 feet, red beds alternate with grayish rocks. The upper 900 feet of the formation is almost entirely red, and of this part the uppermost 350 to 400 feet is bright brick-red in contrast to the duller maroon cast of the beds beneath.

The dolomite and limestone beds are the only beds of the Minturn formation that are persistent over distances of even a few miles, and they are thus almost the only beds that can be used for correlation within this thick formation. Structure can be determined only by "walking-out" these beds, and in practice each of them is mapped, except for a few thin and discontinuous beds in a zone just above the Belden shale. However, only a few of the dolomite and limestone beds have proved to be persistent and distinctive enough—and thick enough—to be useful as marker beds.

Many are nonpersistent or are of only local extent; many have no particularly distinctive features and hence cannot be used with certainty for correlation in badly faulted and heavily covered areas such as at Pando; and many are too thin, and too poorly exposed, to be useful marker beds, even though they may be persistent and distinctive. As the dolomite and limestone marker beds are essential to correlation, and thus to determination of structure, seven persistent, distinctive, and widely exposed beds are designated members of the Minturn formation. The upper four of them have long been known in the Kokomo district, and names are here applied to the three others lower in the section. All the marker beds, as well as practically all the other limestones and dolomites, are in the upper two-thirds of the formation. The lower one-third is almost devoid of carbonate beds except for thin and discontinuous beds just above the Belden shale.

The positions of the members and other stratigraphic features are defined below by their apparent position with respect to the top of the Belden shale as determined by measuring sections from the Eagle River Valley eastward to the crest of the range. Actually, however, the entire formation thins to the east, owing to overlap. Thus successively younger beds form the base of the Minturn formation in going eastward, until finally, on Copper Mountain, north of Kokomo, a limestone which farther west appears to lie 4,200 feet above the Belden has been found by Koschmann[58] to lie just above the pre-Cambrian granite. Under such circumstances, measurements obtained along a line of section several miles long obviously do not express the actual thickness at any one point. This is true, of course, to a certain extent of similar sections of many formations, but in the present case it is a major factor. A stratigraphic thickness of 5,000 feet may be measured between the outcrops of the Belden shale and a given limestone bed, but a vertical bore

[58]Koschmann, A. H., Oral communication.

hole at the limestone outcrop might show only 4,000 feet or less to the base of the formation.

The figures cited serve as well as any others to locate stratigraphic horizons, however, as they are based on the only accessible exposures, and they should cause no confusion if it is understood that they are used for purposes of location and not as accurate expressions of stratigraphic relations at points far removed horizontally or vertically from the outcrop area.

As exposed near Pando, the lower 500 feet of the Minturn formation consists chiefly of white and tan, gritty quartzite and interbedded gray and greenish shale. Several thin and nonpersistent beds of dark dolomite and limestone are present in the lower part of the unit. Some of the quartzite and shale beds have a chalky appearance that suggests that they may contain some volcanic ash, but this possibility has not been checked microscopically.

The quartzite unit is overlain by about 500 feet of reddish rocks consituting the lower red zone. This zone consists of massive, lenticular beds of arkosic grit and conglomerate, and thinner and more uniform beds of shale and arkose. The grit and conglomerate are pink, buff, and pale green; the shale and arkose are maroon. Near the base of the red zone on the slopes east of Camp Hale is a mottled red, green, and buff dolomite bed that is largely replaced by jasperoid and coarse-grained, vuggy, dolomite of hydrothermal origin. This bed, about five feet thick, is known locally as the Jack 8 bed because it is exposed in the discovery pit on the Jack No. 8 claim. Although the bed is covered in many places, and may be discontinuous, it is a useful marker bed wherever it can be found, as it is the only distinctive and relatively persistent bed in the lower 1,800 feet of the Pennsylvanian section.

The lenticular, coarse-grained, arkosic grits and conglomerates of the lower red zone contrast markedly with the more evenly bedded and finer grained quartzite and shales of the underlying zone. This abrupt change probably

reflects abrupt uplift of the Front Range highland, a few miles to the east. The lenticularity and massive cross-bedding of the arkosic grits and conglomerates, the lack of sorting shown by the presence of pebbles and even large cobbles and boulders scattered in the massive grits, the presence of stigmaria and other plant impressions, the presence of local unconformities and scour-and-fill structures, and the irregularly distributed dull reddish color of the rocks all suggest that these are fluviatile deposits. They may represent the coalescing alluvial-fan deposits of a piedmont area lying between the highland to the east and the marine basin to the west, or the floodplain deposits of a large river system, or the head part of a shallow-water delta. Except for a few pebbles of quartzite and chert that probably came from older Paleozoic rocks, the deposits consist entirely of debris from pre-Cambrian rocks and are made up predominantly of pegmatitic and granitic materials. They contain also some of the less resistant pre-Cambrian rocks, however, and the presence of rather abundant green chloritic phyllite indicates that phyllites similar to those of Coal Creek, which belong to a pre-Cambrian series younger than the Idaho Springs formation,[59] were widespread on the Front Range highland during the Pennsylvanian.

The lower red zone of the Minturn formation is overlain by grit, shale, and conglomerate lithologically similar to those of the red zone but generally grayish in color, although individual beds are tinted green, pink, and buff. Three or four beds of black, brown-weathering, cherty dolomite are present in a zone 150 to 200 feet thick lying about 800 feet above the red zone, and one or two discontinuous thin beds of similar dolomite occur at lower levels. The dark dolomite beds in the group 800 feet above the red zone are 2 to 10 feet thick and except for the Jack 8 bed, are the lowest relatively persistent carbonate beds in the section. They are characterized by an abundance of black chert,

[59]Lovering, T. S., and Goddard, E. N., Geologic map of the Front Range mineral belt (explanatory text): Colo. Sci. Soc. Proc., vol. 14, pp. 10-11, 1938.

some of which, locally, may be actually jasperoid. At places in some beds the chert greatly predominates over dolomite. The gray grits in a zone 150 to 300 feet above the upper bed of dark cherty dolomite, or about 2,300 feet above the Belden shale, contain isolated reefs of dark dolomite, particularly in the area north of Resolution Creek. The reefs are 25 to 60 feet thick and 100 to 800 feet in diameter. Some of the reefs, or parts of them, taper gradually to a thin edge; some taper abruptly, with slopes of 30° or more; and some are almost vertical-sided. The reefs consist of dark-gray, brown-weathering, massive, slightly siliceous dolomite, some of which is gritty. They are probably chiefly of algal origin, but locally they contain abundant poorly preserved shell fragments, and most of them contain conspicuous heads of *Chaetetes*. The reef zone is overlain by about 300 feet of grayish grit and conglomerate, above which lies the lowest of the persistent dolomite beds designated members of the Minturn formation.

Wearyman dolomite member.—At 1,600 feet above the lower red zone, or about 2,600 feet above the Belden, is a prominent and persistent bed of light-colored reef dolomite 15 to 75 feet thick. This bed is here designated the Wearyman dolomite member of the Minturn formation. It is named for prominent exposures near Wearyman Creek, which lies in the Minturn quadrangle just north of the edge of the Holy Cross quadrangle. The dolomite is best exposed and thickest on the ridge between Wearyman and Resolution Creeks, at the northern edge of the Holy Cross quadrangle. Here it is a single, massive, reefy bed that pinches to as little as 15 feet in some places and swells abruptly to as much as 75 feet in others. The bottom surface of the bed is almost a plane, and the variations in thickness are caused by domes and hollows on the top surface. The domes are 100 to 500 feet in diameter, and the surfaces of some of them slope as high as 25 degrees. The dolomite is light-gray to buff, finely crystalline, slightly siliceous, and is pitted with small cavities that are elongated in the plane of the bedding.

It weathers to rounded forms but the weathered surfaces are rough and pitted. The dolomite is probably largely of algal origin, although at places it contains abundant remains of crinoids, brachiopods, bryozoans, and fusulinids. Most of the organic structures have been almost obliterated by dolomitization and recrystallization.

Hornsilver dolomite member.—The Wearyman dolomite is overlain by a unit consisting of 300 feet of gray grit, shale, and conglomerate, and one to three thin beds of gray dolomite. At the top of this unit, or about 2,900 feet above the Belden, is a distinctive and persistent bed of gray dolomite and local limestone 18 to 28 feet thick, here called the Hornsilver dolomite member of the Minturn formation. The member is named for outcrops on the south slope of Hornsilver Mountain, where it is best exposed. The dolomite typically shows two divisions. The lower part, 12 to 16 feet thick, is massive and weathers light gray and to characteristic rounded forms, so that a vertical face seen in profile appears smoothly scalloped. The upper part, 8 to 14 feet thick, is thin- and wavy-bedded and weathers dark gray or brownish and to rough slabby forms. The dolomite in both divisions is gray to light gray, medium-crystalline, and slightly porous. At several localities the upper, thin-bedded unit is in part a gray, highly fossiliferous limestone. Fusulinids from this limestone were classified as of Des Moines age by L. G. Henbest of the U. S. Geological Survey while collecting fossils with the writer in 1945. Another bed of gray or brownish, thin-bedded dolomite a few feet thick lies 5 to 10 feet above the main bed of Hornsilver dolomite in most localities, and is separated from it by green or brown conglomeratic grit. On Hornsilver Mountain this upper bed lies 50 to 60 feet above the main bed at one place, where it is 12 feet thick, but the distance between the two dolomite beds decreases rapidly in going toward the crest of the mountain, where they converge in a dolomite reef more than 50 feet thick.

Resolution dolomite member.—The Hornsilver dolo-

mite is overlain by about 400 feet of massive, cross-bedded, gray to yellow and greenish conglomeratic grit. Above this is a zone of thinner-bedded gray grit, shale, and conglomerate about 225 feet thick with three or four thin beds of dark-gray or brownish dolomite near the top. The topmost dolomite bed is overlain by massive green conglomerate about 175 feet thick. This is overlain in turn by the lower of two persistent dolomite beds here designated the Resolution dolomite member of the Minturn formation. The base of this member is 800 feet above the Hornsilver dolomite, or about 3,700 feet above the Belden.

The Resolution dolomite is so named because it caps Resolution Mountain,[60] an 11,927-foot peak on the divide between Resolution and Wearyman Creeks. The member is about 80 feet thick and consists of a lower dolomite bed 35 to 40 feet thick, a middle shale and grit unit 15 to 35 feet thick, and an upper dolomite bed 15 to 22 feet thick. Shale and grit beds interbedded with the lower dolomite, as well as those between the two dolomites, are highly lenticular, and the proportions of clastic rocks and dolomite range rather widely even within the small area at the top of Resolution Mountain. A detailed section showing the character of the Resolution dolomite member is included in the section of the Minturn formation on a following page.

A section of grayish clastic rocks about 400 feet thick lies above the Resolution dolomite and is overlain by the Robinson limestone member. This section is made up principally of grit, shale, and conglomerate, but it contains a few beds of dark dolomite, and near the head of Resolution Creek, a bed of dolomitic grit as much as 30 feet thick. Several discrete dolomite reefs occur at the horizon of this dolomitic grit. The reefs have apparent diameters of 600 to 1,400 feet and are 30 to 140 feet thick. In general they taper gradually to a thin edge, but locally they are steep-sided, with slopes of as much as 60°. They consist of massive, dark-

[60] Although this mountain is named Elk Mountain on one map (Colo. Geol. Survey Bull. 30, pl. 1, 1925), it is known locally as Resolution Mountain because there are both an Elk Mountain and an Elk Ridge within five miles of it.

gray to black, brownish-weathering, somewhat porous, slightly siliceous dolomite. Both the reefs and the dolomitic grit contain numerous heads of *Chaetetes*, and the reefs locally contain abundant crinoid fragments.

Robinson limestone member.—The Robinson limestone, a name used for a group of three limestones in the Kokomo district since the early days of mining there,[61] is here designated a member of the Minturn formation. It lies about 4,200 feet above the base of the formation. It was classed as the basal bed of the Maroon formation by Emmons,[62] and as the basal bed of the "middle unit" of the Pennsylvanian and Permian(?) by Koschmann and Wells.[63] It was classed as a member of the Battle Mountain formation by Brill.[64] Work in the Pando area has proved that the Lime Cliffs group of limestones of the Minturn quadrangle[65] are equivalent to the Robinson limestone, and that the bed Brill[66] designated the Robinson limestone in his type section of the Battle Mountain formation, along Turkey Creek, in the southern part of the Minturn quadrangle, is in reality the bed here called the Hornsilver dolomite.

The Robinson member in the Pando area is 300 to 400 feet thick and comprises 3 to 5 beds of gray limestone separated by clastic rocks. The limestone beds are 3 to 21 feet thick and 40 to 85 feet apart. The clastic rocks separating them consist of interbedded conglomerate, grit, and shale, and are red, gray, and green in color. The red beds alternate with the gray and greenish beds, and they mark the beginning of the transition from grayish rocks in the lower part of the Pennsylvanian and Permian(?) section to

[61]Emmons, S. F., Geology and mining industry of Leadville, Lake County, Colorado: U. S. Geol. Survey 2nd Ann. Rept., p. 220, 1882.

Emmons, S. F., U. S. Geol. Survey Geol. Atlas, Tenmile district special folio (no. 48), pp. 2, 4, 1898.

Koschmann, A. H., and Wells, F. G., Preliminary report on the Kokomo mining district, Colorado: Colo. Sci. Soc. Proc., vol. 15, p. 65-66, 1946.

[62]Op. cit. (1898).

[63]Op. cit. (1946).

[64]Brill, K. G., op. cit. (1942), p. 1388.

[65]Lovering, T. S., and Tweto, O. L., op. cit., p. 43 and map.

[66]Brill, K. G., op. cit. (1942), p. 1380.

red rocks in the upper part. Where unaltered, the limestone beds of the Robinson member are dark gray and fine-grained, and they weather light bluish gray. Locally they contain siliceous material in irregular small seams and clots that weather out in relief, and at a few places they contain a little chert. The limestones are thin-bedded to massive, and locally they grade into calcareous black shale. The massive beds appear to be pure limestone of lithographic texture. The thin-bedded material has a knobby or nodular structure, contains clots and partings of shaly material, and has rough, irregular bedding surfaces. The limestones are fossiliferous and are characterized particularly by fusulinids. These were classed in the field as Des Moines in age by L. G. Henbest, as were collections of fusulinids and of larger fossils from the Kokomo district.[67] All the limestone beds of the Robinson member in the Pando area are partly replaced by tan or buff, coarsely crystalline, vuggy hydrothermal dolomite, and the lowermost bed is everywhere almost completely replaced.

Elk Ridge limestone member.—A limestone which in the Pando area lies 275 feet above the Robinson member, or about 4,800 feet above the Belden shale, is known as the Elk Ridge limestone at Kokomo[68] and is here designated the Elk Ridge limestone member of the Minturn formation. The section between the Robinson and Elk Ridge members consists of red conglomerate and grit alternating with gray grit and dark shale. The Elk Ridge member in the Kokomo district comprises two limestone beds separated by 200 to 225 feet of red sandstone and conglomerate, but in the Pando area it is a single limestone bed 7½ to 21 feet thick. Where it is thickest, on Radio Ridge, this bed consists of three feet of dark, fine-grained, thin-bedded dolomite, overlain by 10 feet of mottled gray and pink, slightly sandy, locally oolitic limestone. Fossils are rare in the limestone and are poorly preserved. Throughout the Pando area the

[67]Koschmann, A. H., and Wells, F. G., op. cit., p. 66.
[68]Koschmann, A. H., and Wells, F. G., op. cit., p. 67.

Elk Ridge limestone is partly replaced by tan hydrothermal dolomite, like the Robinson limestone.

White Quail limestone member.—A limestone which in the Pando area lies 150 to 200 feet above the Elk Ridge limestone member, or about 5,000 feet above the Belden shale, has long been known as the White Quail limestone in the Kokomo district.[69] It is here designated the White Quail limestone member of the Minturn formation. Grit, shale, and conglomerate lying between the Elk Ridge and the White Quail members are all maroon in some places and are alternating light gray and maroon in others. The White Quail is exposed only on the top of Ptarmigan Hill and on Radio Ridge in the Pando area. On Ptarmigan Hill it consists of 8½ feet of black dolomite, dolomitic shale, and black fossiliferous shale. On Radio Ridge it consists of 10 feet of dark-gray or brownish-gray limestone and dolomite that weather dark blue green. The bed appears massive but is made up of alternating thin lenses of the limestone and dolomite. Most of the limestone is oolitic. The bed contains fairly abundant gastropods, and some bedding planes show numerous casts of cephalopods, pelecypods, and brachiopods as well.

Although the age of the White Quail limestone has not been fixed with certainty, it is more likely Pennsylvanian than Permian. Fossils from the White Quail of the Kokomo district, according to James Steele Williams,[70] ". . are not certainly distinctive of any part of the Pennsylvanian" but ". . the aspect of the fauna is that of the Hermosa formation, and the general resemblances are definitely to beds of Des Moines or early Kansas City age, rather than to later Pennsylvanian or to Permian." Brill[71] reports *Mesolobus mesolobus,* a Des Moines index fossil, in bed 204 of the type section of the Battle Mountain formation, a few miles north of the Pando area. This bed is approximately at the horizon of the

[69]Emmons, S. F., op. cit. (1898), p. 4.
[70]Koschmann, A. H., and Wells, F. G., op. cit., p. 68.
[71]Brill, K. G., op. cit. (1942), p. 1379.

White Quail limestone, and it may be equivalent to the White Quail.

Jacque Mountain limestone member.—The White Quail limestone is overlain by about 150 feet of maroon limy siltstone which is locally mottled pale green, and the siltstone is overlain by about 800 feet of maroon and brick-red grit, conglomerate, arkose, and shale. About 950 feet above the White Quail limestone and 5,900 feet above the Belden, is a persistent and distinctive limestone that has long been known as the Jacque Mountain limestone. This limestone was the top member of the Maroon formation as recognized by Emmons in the Kokomo district[72] but was within the Maroon as later recognized by the U. S. Geological Survey.[73] It was classed as a member of the Battle Mountain formation by Brill[74] and was recognized as the top bed of the "middle unit" of the Pennsylvanian and Permian(?) by Koschmann and Wells.[75] It is here designated the Jacque Mountain limestone member of the Minturn formation, and the top of the limestone marks the top of the Minturn formation as here defined.

The Jacque Mountain limestone is one of the most distinctive and persistent beds in the eastern part of the Pennsylvanian and Permian(?) basin of west-central Colorado. From the Kokomo area it is persistent northwestward for at least 25 miles to the northwest corner of the Minturn quadrangle,[76] and its prominent development there suggests that it continues northwestward beneath the volcanic field at and southeast of State Bridge.

The Jacque Mountain member consists typically of 15 to 25 feet of dark bluish-gray to light-gray, fine-grained limestone, some part of which is characteristically oolitic. The limestone weathers light gray or bluish and at most

[72]Emmons, S. F., op. cit., pp. 2, 4.

[73]Wilmarth, M. G., Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, pt. 1, p. 1039, 1938.

[74]Brill, K. G., op. cit. (1942), p. 1385.

[75]Koschmann, A. H., and Wells, F. G., op. cit., p. 62.

[76]Lovering, T. S., and Tweto, O. L., Preliminary report on geology and ore deposits of the Minturn quadrangle, Colorado: U. S. Geol. Survey Open file report, p. 46, and map, 1944.

places shows some pinkish mottling. It is a single massive bed in some outcrops and is thin- to medium-bedded in others. Much of the limestone appears to be quite pure, but locally some beds are sandy or gritty, and at a few places the limestone contains considerable limy shale, sandstone, and conglomerate. Locally it contains beds or lenses of spotted pink and gray intraformational limestone conglomerate.

One of the distinctive features of the Jacque Mountain limestone is the presence in most localities of a few scattered large cephalopods, both coiled and straight. The limestone contains also a few large gastropods at places, and in the region northwest of Kokomo, pinkish concentric algal colonies are prominent in one or two beds within the member. Cephalopods and gastropods from the Jacque Mountain member in the Kokomo district have been examined by James Steele Williams and A. K. Miller, who found them to be long-range forms that might be either Pennsylvanian or Permian, but both believe that the fossil evidence slightly favors a Pennsylvanian age.[77]

Age of the Minturn formation.—At least the lower five-sixths of the Minturn formation is of Des Moines (middle Pennsylvanian) age, as the Belden shale of this area is of Cherokee (lower Des Moines) age,[78] and the White Quail limestone member is very probably of Des Moines age, as has been shown above. If the Jacque Mountain limestone member of the Minturn formation is of Pennsylvanian age, the entire Minturn is Pennsylvanian. If the Jacque Mountain limestone member is of Permian age, the Pennsylvanian-Permian boundary must lie somewhere between the White Quail and the Jacque Mountain members. This seems unlikely, however, because no unconformity or lithologic break has been found in this part of the section, and it seems unlikely that the 900 feet of beds between the White Quail and Jacque Mountain members represents all the time be-

[77]Koschmann, A. H., and Wells, F. G., op. cit., p. 69.
[78]Brill, K. G., op. cit. (1944), p. 626.

tween the Des Moines and the Permian. These beds are of the same general character as the rest of the Minturn formation, and they were therefore presumably deposited just as rapidly as the lower 5,000 feet of the formation. If 5,000 feet of coarse sediments was deposited during only a part of Des Moines time, it is unlikely that 900 feet of the same type of coarse sediments represents all of the upper half of the Pennsylvanian unless there were breaks in sedimentation. As no evidence of such breaks has been seen, however, except in the narrow belt of sharp overlap along the old shoreline,[79] the Jacque Mountain limestone is inferentially of Pennsylvanian age.

Sections.—Although segments of the Minturn formation as much as 2,000 feet thick are well exposed at several places along the Eagle River between Minturn and Pando, the entire formation is not well exposed at any one locality. The formation typically forms smooth slopes on which outcrops are discontinuous if not rare, and in the Pando area it is heavily faulted. Detailed sections therefore can be measured only in segments which must be correlated from exposure to exposure or fault block to fault block by whatever means possible. Sections compiled by measuring a few hundred feet here and a thousand feet there have the disadvantage of not showing the character or thickness at any one place, but unless the geographic spread is too large, they do give thicknesses that are approximately accurate, and they show the general character of the formation reasonably well.

The group of sections given below, and on which the preceding discussion is largely based, follow an irregular line that extends, in going down-section, from the Jacque Mountain limestone on the north end of Radio Ridge (fig. 2) southward to the White Quail limestone on the south end of the ridge; from the White Quail on the top of Ptarmigan Hill southwestward down the slope to the Resolution dolomite; from the Resolution dolomite on top of Resolution

[79]Koschmann, A. H., and Wells, F. G., op. cit., pp. 86-87.

Mountain southward down the slope to the Hornsilver dolomite; from the Hornsilver dolomite on Hornsilver Mountain southwestward down the ridge between Coal and Silver Creeks to the top of the Leadville dolomite at the foot of the big slide scarp south of the mouth of Silver Creek, about 1.5 miles north of Pando. The sections indicate a thickness of about 6,000 feet along this line, but as shown above, this figure does not express the actual thickness at any one point along the line. Moreover, although the total might be similar along another line of sections to the north or south, the distances between members would probably differ appreciably. South of Resolution Creek, for example, the section between the Belden shale and the Wearyman dolomite member of the Minturn formation seems to be 200 to 500 feet thicker than in the area north of the creek. On the other hand, the section between the Wearyman member and the Robinson member is somewhat thinner than in the area to the north; but again, the distance between the base of the Robinson member and the White Quail member is increased. Similar relations prevail in an east-west direction. The section between the base of the Minturn formation and the Robinson member thickens westward, but the section between the Robinson member and the White Quail member thins westward.

Section of the Minturn formation from top of the Jacque Mountain limestone member to top of White Quail limestone member. Radio Ridge.

(Section not measured in detail; thicknesses computed from structure section. Porphyry sills omitted.)

Unit		*Feet*
	Minturn formation:	
	Jacque Mountain limestone member:	
10	Limestone, irregularly oolitic, gray and pinkish, thin- to medium-bedded; slightly sandy, and top grades from gritty limestone to limy red grit; red micaceous siltstone and green clay shale on some bedding planes. Contains rare recrystallized fragments of cephalapods, and a few elliptical algal structures. Base not exposed.	15

Unit		Feet	
9	Arkose and siltstone, brick red, thin-bedded. Lenses of red grit and conglomerate.	100	
8	Grit and conglomerate, brick red, some interbedded red shale. Much of conglomerate is coarse, with cobbles up to 6 inches in diameter.	190	
7	Shale, siltstone, and thin-bedded arkose, all brick red. Lenses of red grit.	80	
6	Conglomerate and coarse grit, maroon, massive. Conglomerate contains cobbles up to 8 inches in diameter.	160	
5	Grit, shale, arkose, and siltstone; maroon, thin-bedded.	120	
4	Siltstone, slightly limy, maroon; and thin beds and lenses of gray, nodular limestone.	75	
3	Grit, shale, and lenses of conglomerate; maroon, mostly thin-bedded.	60	
2	Limy siltstone, maroon with greenish mottling, massive but finely laminated in part. Contains thin lenses of gray limestone, and a 3-foot bed at base.	120	
1	Shale, arkose, and grit; maroon; thin-bedded. Top of White Quail limestone member.	30	
	Top of Jacque Mountain limestone member to top of White Quail limestone member:	935	(±50)

Section of Minturn formation from top of White Quail limestone member to top of Resolution dolomite member; from top of Ptarmigan Hill down spur to southwest.

Minturn formation:

White Quail limestone member:

101	Dolomitic shale, black, slightly micaceous, thin-bedded, contains abundant small (¼-inch) spiriferoid brachiopods. Gradational contacts with shale above and below.	2
100	Shale, black, non-micaceous, massive, with small nodules black dolomite; contains small (¼-inch) spiriferoid brachipods. (Offset on top of dolomite, across faults, to cairn on top Ptarmigan Hill.)	3
99	Dolomite, black, brown-weathering, finely crystalline, thin-bedded; smooth grooves and small breccia fragments show on weathered surface. Contains recrystallized fusulinids and ostracods(?).	2.5
98	Grit, green, medium-grained, thin-bedded.	2.5

Unit		Feet
97	Grit, pink to maroon, coarse-grained, thin-bedded; nodules and small lenses of pinkish- and greenish-gray limy grit at base, and of dolomitic grit near middle.	13
96	Shaly grit, maroon, strongly micaceous, thin-bedded and platy; some bedding planes grayish and slightly limy; occasional mud cracks. Thin beds and lenses maroon micaceous dolomitic shale.	18
95	Grit and interbedded shaly grit; maroon, thin- to medium-bedded, strongly cross-bedded; thin streaks and lenses slightly limy.	15.5
94	Conglomeratic grit, pink to maroon, massive; scattered small blotches of gray or greenish limy grit.	7
93	Gritty shale, maroon, highly micaceous, thin-bedded.	2.5
92	Conglomerate and lenses of grit; maroon, massive; pebbles of pre-Cambrian rocks 4 inches in maximum diameter; a few thin lenses of highly micaceous, green and maroon shale.	30
91	Grit, maroon, coarse-grained, massive, cross-bedded.	8.5
90	Shale, maroon, sandy and highly micaceous, thin-bedded.	4
89	Grit, maroon, fine- to coarse-grained, thin-bedded; contains scattered pebbles and cobbles up to 6 inches in diameter.	4.5
88	Conglomerate, pink, coarse-grained, friable; pebbles of pre-Cambrian rocks, up to 6 inches in diameter.	3
87	Shale and thin beds and lenses of grit and conglomerate; maroon, micaceous, thin-bedded; nodules of maroon and green shaly dolomite at top.	17.5
86	Conglomerate and interlensed grit; maroon, thin-bedded to massive, cross-bedded; pebbles of pre-Cambrian rocks, up to 5 inches in diameter.	12
85	Shale, maroon, highly micaceous, sandy, thin-bedded; minor green mottling in lower ⅓ and at top.	10.5
84	Limy grit, maroon, medium-grained.	1
	Elk Ridge limestone member:	
83	Dolomite, greenish tan, sandy, medium-crystalline; nodular, with greenish-tan clay matrix.	1.5
82	Dolomite, sandy, gray to tan, thin-bedded.	1
81	Limestone, gray and slightly pinkish, blue-gray-weathering; upper 1 foot micaceous,	

Unit		Feet
	thin-bedded, and streaked by thin partings of maroon and greenish micaceous shale; limestone contains a few gastropods and some possible algal structure.	3
80	Dolomite, light gray, coarsely crystalline, tan-weathering. Hydrothermal dolomite in irregular contact with limestone above; irregular tongues of dolomite extend into the limestone, and irregular remnants of limestone are enclosed by the dolomite. Sandy at base.	2
79	Shale, gray, highly micaceous, soapy.	1
78	Shale, gritty, highly micaceous, mottled maroon and greenish, thin-bedded.	4
77	Shale, mottled green and maroon, highly micaceous.	4
76	Grit, greenish gray, with minor maroon mottling; massive, coarse-grained.	2
75	Shale, green-gray, highly micaceous, soft, thin-bedded; and a little interbedded gray, fine-grained, limy arkose in 2- to 4-inch beds.	13
	Local unconformity. Contact of shale with underlying, strongly cross-bedded massive grit is wavy; strong angular discordance between shale and grit locally.	
74	Grit, light green-gray, coarse-grained, thin-bedded to massive, strongly cross-bedded; contains scattered pebbles 3 inches in maximum diameter.	41
73	Shale, dark green, micaceous; and interbedded gray limy grit.	2
72	Grit, light gray, medium-grained, thick bedded; partings of black, dark-green, or brownish micaceous shale between beds.	13.5
71	Grit and interbedded shale; grit thin-bedded, gray to tan; shale dark-gray and black, micaceous.	11
70	Shale, black, micaceous, with thin beds brown grit, and nodules of gritty shale.	5
69	Arkose and interbedded shale; arkose thin-bedded, brownish gray, highly micaceous; shale dark gray to black, micaceous, much of it sandy. Shale fragments on bedding planes of arkose beds.	13
68	Shale, black and dark green-gray, micaceous, massive; several ½- to 1-inch beds brown arkose.	30
67	Arkose and interbedded shale; arkose gray, brownish, and dark blue-gray, thin-bedded, highly micaceous; shale dark gray to black, micaceous, and sandy in part. Plant fragments in some of the shale beds.	16

Unit		Feet
66	Shale, dark gray to black, micaceous, sandy, thin-bedded.	12
65	Grit, light-gray, medium- to thick-bedded, cross-bedded.	14
64	Shale and interbedded arkose and grit; shale black, mostly micaceous and sandy but some clay shale near base; arkose and grit dark gray and brown, thin-bedded. Interval contains cyclothemic coal successions at 3 and 23 feet above base. Lower cyclothem represented by 1 foot of chalky, gritty, underclay, with a cast of stigmaria 15 inches in diameter, ¼ to ½ inch of coaly material, and 6 inches of rusty, highly micaceous, dolomitic grit; upper cyclothem represented by 4 to 6 inches of gritty underclay with a few small root impressions, ½ inch of woody-coaly material, and 8 to 10 inches of rusty, highly micaceous, dolomitic grit. Interval is not well exposed and may contain other cyclothemic coal successions.	39
63	Shale, mottled maroon and green, micaceous.	1
62	Conglomerate, pink and maroon, massive; becomes coarser upward; cobbles of pre-Cambrian rocks 9 inches in maximum diameter	27
61	Grit, maroon, slightly conglomeratic, massive, cross-bedded.	16
	Robinson limestone member:	
60	Limestone, gray and pinkish gray, locally micaceous, and streaked by maroon and green micaceous shale. Limestone has irregular nodular structure, and some of it has brecciated appearance on weathered surface. Limestone irregularly replaced by coarse-grained, light-gray, tan-weathering, vuggy, hydrothermal dolomite. Limestone contains fusulinids and gastropods.	5
59	Shale, maroon with greenish-gray mottling, micaceous, soft, thin-bedded. A few thin beds maroon shaly arkose.	16.5
58	Grit, maroon, medium- to coarse-grained, thin-bedded, cross-bedded, some micaceous shale partings near base.	24
57	Interbedded maroon micaceous shale and thin-bedded maroon micaceous arkose. Minor green mottling in shale.	15
56	Shale, green, micaceous, soft; and some interbedded thin-bedded, pink and green shaly arkose. Shale contains small fossiliferous nodules of black limestone.	4.5

Unit		Feet
55	Shale, calcareous, non-micaceous, black; contains rich brachiopod fauna and some horn corals and bryozoa. Lower half of unit contains thin nodular beds of highly fossiliferous black limestone, and a 1-foot bed of black crystalline dolomitic limestone at base contains a few poorly preserved fusulinids. A few thin beds of micaceous, sandy, nonfossiliferous shale in middle of unit. This unit grades into a 12-foot bed of gray limestone on the slope a few hundred feet to northwest	15
54	Shale, dark gray, highly micaceous, gritty.	1
53	Grit, white, coarse-grained, massive, cross-bedded.	9
52	Shale, green, micaceous, soft; and interbedded maroon, thin-bedded arkose.	6
51	Grit, pink, coarse-grained, massive, strongly cross-bedded.	7
50	Shale and shaly arkose, maroon and green, highly micaceous, thin-bedded.	3
49	Conglomerate, pink and maroon, coarse-grained; boulders of pre-Cambrian rocks 14 inches in maximum diameter.	17
48	Dolomitic grit, green and maroon.	1
47	Shale, green, micaceous, soft.	1
46	Conglomerate and coarse grit, maroon, massive; contains boulders 12 inches in maximum diameter.	9
45	Shale, green and maroon, highly micaceous.	2
44	Conglomerate and coarse conglomeratic grit, maroon and pink with some green mottling.	17
43	Limy grit and arkose, maroon, with yellowish or brownish mottling in more limy spots. Strongly cross-bedded.	14
42	Limestone, gray with minor pink mottling; irregular nodular or breccia-like structure, with green or maroon micaceous shale streaks and irregular pockets. Contains abundant fusulinids, crinoid stems, echinoid spines, and a few gastropods and brachiopods. Fifty feet to the east the limestone grades into brownish-maroon limy conglomerate, similar to that below the limestone.	4
41	Limy conglomerate, brownish maroon; 6 inches of maroon micaceous shale at top.	4
40	Grit and conglomeratic grit, maroon, coarse-grained, thin-bedded to massive, cross-bedded.	16
39	Limestone; lower 10 feet massive, gray and pink; next 5 to 6 feet thin-bedded, nodular, has breccia-like structure, and weathers	

Unit		Feet
	rough; next 2 to 3 feet thick-bedded, pinkish gray, sandy; top 2 to 3 feet medium-bedded, blue gray, weathers smooth and rounded. Limestone irregularly replaced by coarse, light-gray, tan-weathering, hydrothermal dolomite. Limestone contains abundant fusulinds, brachiopods, bryozoans, gastropods, and crinoid and echinoid fragments.	21
38	Covered, probably black shale.	5
37	Shale, greenish black, micaceous; coal cyclothemes between 8 and 10 feet above base consist, from bottom to top, of 2 to 4 inches gritty root clay, 1 inch of coaly black shale, and 1 to 3 inches of rusty dolomitic grit; this sequence is repeated twice.	26
36	Dolomite and limestone: Discontinuous thin pods of limestone, dolomite, and dolomitic grit. Limestone gray, contains abundant algal structures, crinoid fragments, and fusulinids. (Henbest collection F 5796.) Dolomite black and slightly sandy; grades into coarse, rusty dolomitic grit.	1
35	Arkose, gray, slightly dolomitic, thin-bedded; contains a few plant stem impressions.	3.5
34	Shale, dark greenish-gray, micaceous, massive.	6.5
33	Limestone, dark bluish-gray, thick-bedded, smooth-weathering; locally some brownish-gray thin-bedded dolomite at base. Limestone contains fusulinids, (Henbest collection F 5794).	2
32	Shale, dark greenish-gray, micaceous.	2.5
31	Conglomerate and coarse grit, green gray, thin-bedded to massive, cross-bedded.	7
30	Shale, green, micaceous, soft; and interbedded maroon and greenish, highly micaceous arkose. Arkose in lower part of unit is slightly dolomitic.	7.5
29	Conglomerate and coarse grit, grades from pink and greenish conglomerate at bottom to maroon grit at top; massive, cross-bedded.	17.5
28	Interbedded shale, grit, and arkose in thin beds. Shale green and maroon, micaceous; grit and arkose maroon, thin-bedded. Lower half of unit is mostly arkose and arkosic shale	7
27	Dolomite, light gray, coarsely crystalline, tan-weathering, vuggy; gritty near base. Dolomite is hydrothermal and has replaced gray limestone, remants of which occur in this bed 1 mile to northwest. Dolomite retains the patchy, breccia-like structure and threads and streaks of highly micaceous shale characteristic of the gray limestone.	5