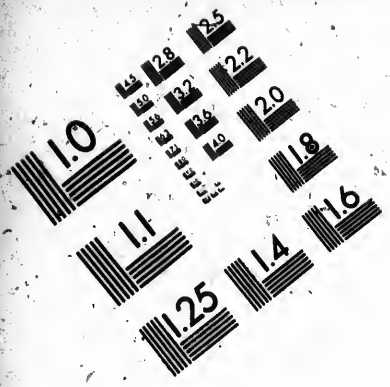

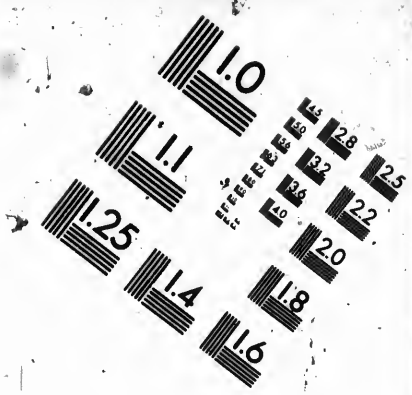

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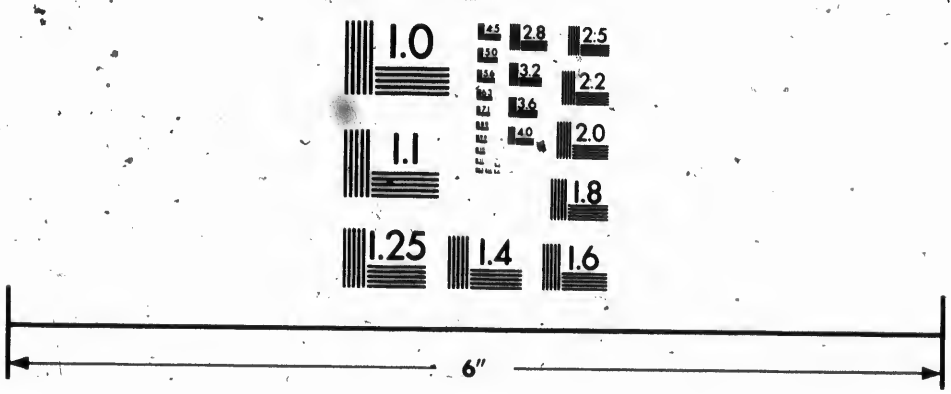

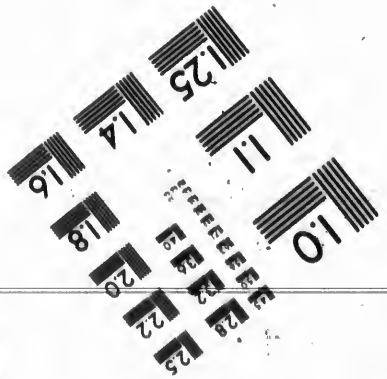

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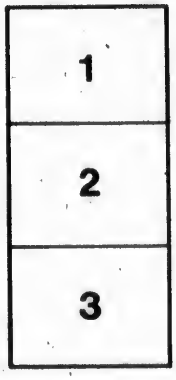

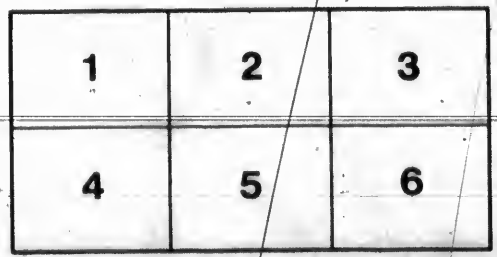

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Canadian Society of Civil Engineers.

INCORPORATED 1887.

TRANSACTIONS.

LOCATION AND CONSTRUCTION OF THE GREAT NORTHERN RAILWAY IN THE ROCKY MOUNTAINS.

By Jas. H. Kennedy, M. Can. Soc. C.E.

The Great Northern Railway system, composed of the old St. Paul, Minneapolis & Manitoba, Montana Central, Eastern Minnesota, Fairhaven & Southern and other railways, under the control of Mr. J. J. Hill, is the last addition to the increasing number of transcontinental railways competing for business between the Pacific slope and the East. The surveys for the Pacific extension of this system were begun in the year 1889, and, with the exception of the Cascade tunnel construction were finished in 1892, so that by the use of a switchback in the Cascades, the line was opened for through business. This line is unique in being the only through line ever built over the Rocky Mountains without government aid either as a subsidy or land grant; and it is claimed to have advantages in the way of grades, distance, etc., over its competitors. This of course is the second line over the summit of the Rocky Mountains owned by this company, the other being from Helena to Butte City, Montana.

This paper is written with a view to giving the members of our Society a little information with respect to the details of the surveys and construction in the main range of the Rocky Mountains, with the hope of provoking a discussion that may elicit from others possessing it, more complete information; as well as to draw forth a comparison with the other transcontinental lines, or with similar work elsewhere; but let it be remembered that the information here intended to be given is limited to the Rocky Mountain section, or say to the part between Havre on the east and Kalispell on the west side of the range,—a distance of 260 miles. Of this 260 miles the first 150 from Havre to Blackfoot was mostly ordinary prairie work, and offers nothing specially interesting, except indeed the two high bridges crossing the Cutbank and Two Medicine Creeks. These bridges will be noticed later. Again, on the west side from Coram to Kalispell, 25 miles cannot be said to be mountain work, although quite as heavy in one or two places. That leaves an intermediate distance of some 85 miles that may fairly be called mountain work, and it is to this latter district that this paper is more particularly intended to apply. (See Map, Plate VI.)

The general route selected to be explored was through the Marias Pass and down the Flathead River to the Flathead Valley, and the exploration was made in the winter of 1889 and 1890 with great difficulty, by an engineer on snow-shoes, aided by old trappers and hunters. The plan decided on was to start in from the west side of the range and follow up the middle fork of the Flathead River to as near as possible to the Marias Pass, and to return from the Pass by following down a creek, since called Summit Creek, some 12 miles to its outlet into the Middle Fork of the Flathead, thence down this latter river to the Flathead Valley. The difficulties and hardships met with in making this trip in midwinter with several feet of snow on the

ground in the face of cold and hunger, and in which the participants were at one time feared to have been lost, cannot be very well described, but can be appreciated by those who subsequently passed over the same ground. The route, however, was reported as quite favourable, the elevation of the summit being about 5200 feet, with no insurmountable difficulties to be overcome.

The route leading up to the Pass from the East had been known for some time to be quite practicable, the writer being unable to say who explored it, or who discovered the Pass. It is claimed by some, however, that the Pass was known to the Indians for nearly a century, and had been used by traders of the Hudson Bay Company. Be that as it may, there is still to be found the evidence of an old and pretty well defined trail leading up towards the Pass from the west side, but it divides up and becomes so obscure in places that it is hardly possible for a stranger to follow it up. Indeed, a party who made the attempt was after 10 days search for the Pass compelled to return for a guide without having found it.

In the spring of 1890, three survey parties were placed in the field to make preliminary surveys. One party started westward from Havre. The second was started nearer the foot of the mountains to work westward, while the third was started from the west side of the range with instructions to work eastward up the middle fork of the Flathead river to meet the other party working westward in the mountains.

The progress of surveys in the mountains was necessarily slow on account of the difficulties to be overcome. Supplies had to be forwarded by pack train, and the trail had to be cleared, and in places graded. Again, the season was very wet, indeed it rained more or less every day from the 12th of May until the 4th of July. This kept the stream crossings so high that supplies had to be ferried on rafts and the horses had to swim. Another difficulty was the scarcity of horse feed, there being but a very few places where grass could be found at all; consequently, when the pack train arrived at camp with a cargo, it was always necessary, rain or shine, to move camp hurriedly, and get the horses out to feed as quickly as possible. This, of course, made moving camp very disagreeable, as the rain never omitted to pour on moving days. The two parties in the mountains met on the 30th of July, about 20 miles west of the summit, and, according to instructions, each turned and located back over its own preliminary.

On the prairie, of course, camp outfits and supplies were moved forward by wagons, but in the mountains the pack train was the only way practicable. The usual load for a pony or cayuse was from 150 to 200 lbs., and the average expense 75 cts per day for each animal, with $60 per month for the "head packer," and $40 to $45 for each assistant. A man who doesn't understand the "diamond hitch," by which the pack is "cinched" to the horse, is useless with a pack train. This work was all done with hired animals, but it is very probable that it could be done as economically and in other ways more satisfactorily by purchasing the animals and placing an experienced man in charge of them.

There were a few places along Summit Creek and on the Flathead that showed evidence of former snowslides where the timber had been stripped off in streaks from the top of the mountain to the bottom; but there seemed to have been no slides of recent occurrence, and they had no influence on the location, the plan adopted being to make the location to suit the ground, and decide on the protection of the roadbed from snowslides afterwards if it should be found necessary. From the summit down Summit Creek, the fall is such that the grade (a 1.8 p.c.) crosses the Flathead at the mouth of the creek about 140 feet above the water, and the valley of the middle fork of the Flathead from here for a few miles down the river may be said to be reasonably straight. This valley, however, is about 120 feet above the water, and the stream meanders from side to side, so that at each point where the stream cuts into the side of its valley, there is a cut bank extending up the side to a higher bench. The work of carrying the survey lines over the face

of some of these cut banks was both difficult and dangerous on account of the liability to slip down, and also on account of the stones that were continually dropping as they became loosened. The material was cemented gravel. Further down the river the rock closed in on both sides, forming a canon for several miles. Through this canon the grade line was carried about five feet above high water mark.

The following instructions for the location were given by the chief engineer, viz.:—

Limit of curvature,	10°
Shortest tangent,	200′

These limits were slightly adhered to during the location. There were no transition curves used, strictly speaking, in the location, but, where practicable, the sharper curves had one or two stations at beginning and ending with twice the radius. For instance, a 10° curve would begin and end with a station or two of a 5 where there was room to get it in.

The following data were also laid down by the chief engineer as a guide in making location, viz.:

One foot in distance is worth $10.
" " rise and fall up to 10 ft. is worth nothing.
" " " " over 10 ft. " " $500.

Or in other words, a summit of 100 ft. is equal to a mile around.

One degree of curvature is worth $50, or that amount might be expended in order to eliminate one degree of curvature.

These, of course, were not intended to be very exact values for curvature, distance, or rise and fall; but considered to be somewhere near the truth, or near enough for all practical purposes; so that, by using these figures in calculating alternative locations, no very great error of judgment could take place in deciding which to adopt. These figures, with a list of approximate prices for rock, earth, bridging tunneling, etc., were adhered to during the location, which was completed with the exception of a few minor revisions in January, 1891.

As to grades, suffice it to say that the summit is reached from the east with a maximum grade of one per cent. From Summit to Essex, about 14½ miles, there is a down grade of 1.8 per cent, and from Essex westward to and across the Flathead country, the maximum down grade is 0.8 per cent. with a maximum of 0·6 per cent. against westbound traffic. Compensation for curvature at the rate of .04 per degree was used on all maximum grades.

In the fall of 1890, while the location in the mountains was progressing, a supply road was begun from each side of the range and carried to completion shortly after the completion of the location, or about the first of February, 1891. The weather during the early winter had been very favourable, and very little snow had fallen; otherwise it is doubtful if the supply road could have been completed that winter, as snow began to fall on the 1st February and continued until it was six or seven feet deep. It continued quite stormy until April. The supply road, however, was no sooner completed than contractors were on the ground engaged in hauling in supplies and opening up their heavy rockwork.

Construction operations were carried on simultaneously from both sides of the range. The necessary supplies for the west side had been shipped from St. Paul to Ravalli, a station on the Northern Pacific, west of Missoula, and hauled from there 30 miles to the foot of Flathead Lake. Thence taken by steamboat to Demersville, 60 miles, and stored there before the close of navigation on the Lake. Demersville thus became a distributing point for the work both east and west of the Flathead country.

Grading was classified under the four following heads: solid rock, loose rock, cemented gravel and earth; and the following may be quoted from the classification, viz.:

"Solid rock will include all rock in place (except slate, shale and sand rock, and disintegrated granite that can be removed without frequent drilling and blasting), and detached rocks or boulders which measure

one cubic yard or more, in removing which it is necessary to resort to drilling and blasting.

"Loose rock will include all detached masses of rock measuring one cubic foot and less than one cubic yard, and all slate, shale, sand rock, and disintegrated granite, which can be removed by picks and bars without frequent drilling and blasting, although blasting will be occasionally resorted to.

"Cemented gravel will include compacted earth, hard pan, cemented gravel deposits, and all material, except solid rock and loose rock, as above described, which cannot practically be plowed.

"Earth will include all material in excavation of every description not embraced in the foregoing classifications for solid rock, loose rock, and cemented gravel.

"Embankment will include all borrowed material for formation of roadbed or for other embankments wherever required."

The free haul for earth was 300 feet, and for classified material 1000 feet. When the haul extended beyond 1000 feet, embankment price was added to the price paid for excavation.

The rock was not a very difficult material to handle in most cases. It varied from slate and sand rock to a hard brittle quartzite, and all tilted up to a dip of about 40 degrees to the northwest. There were a few instances of cemented gravel that were as difficult to remove as rock, or more so, where powder had to be used to shake up the material; but in general the material varied so that it was difficult at times to decide what classification should be given. The method adopted, however, was to classify the harder material as cemented gravel and the looser as earth, with a varying percentage of classified material according to hardness. It will be noticed that the specification for cemented gravel is somewhat elastic, and leaves considerable to the engineer's opinion as to what he considers "may practically be plowed."

While such a clause as the above in the specification very often enables an engineer to do justice by a contractor by giving him the benefit of the doubt when it might otherwise be impossible, nevertheless it has a tendency to induce contractors to take work at a price they know to be too low with the expectation of getting classified out by the engineer, and this is an evil that appears to be increasing more and more as competition becomes closer.

There are five tunnels in the district under consideration, all west of the summit. They vary in length from 180 to 780 feet, the total amounting to about 1,600 feet of tunneling. Of this, the whole, with the exception of about 150 feet, is timbered. There were no special difficulties connected with the tunnels, the whole being in rock, and sufficient timber was obtained close by. The timber used was hewn tamarack and red fir. Logging was of red fir 4" x 6". Tunnel work was let at a stated price per lineal foot for the standard dimensions, and when necessary to be enlarged for timbering the increase in size was paid for per cubic yard. Timbering was paid for at a rate per M. ft. B.M. The drilling was all done by hand. (See Standard Sections, Plate V.)

There are four high wooden bridges in the district under consideration: two on the east side of the range crossing the Cutbank and Two Medicine Creeks, and two crossings of the Flathead river on the Western slope. The Cutbank bridge is about 1,200 feet long and 180 feet high, and consists of 4 spans of 120 feet each and the rest 16 feet spans. The Two Medicine bridge is probably one of the highest timber trestles ever erected, being 751 feet long and 211 feet high. It consists of one span of 120 feet, 4 spans of 40 feet each, and the rest 16 feet spans. This bridge contains about 750 M. ft. B.M. of timber. (See Plate VIII.) The two crossings of the Flathead river are 140 and 90 feet high respectively, and each contains 2 long spans and a number of 16 feet openings; but writing from memory, definite figures cannot be here given, and indeed it is possible some of the heights or lengths given may be found to be slightly in error.

The special features of these high trestles are continuous posts from foundation to cap, packed at every story with a 4" x 12" plank 6' long. (See Plate VII.) The stories are all 17½ feet high, so as to permit the use of 18 feet lengths in posts, and also to avoid using too long pieces in the longitudinal and sway braces. Long timber is not very plentiful in Montana. The inside posts have a batter in order to afford a better system of bracing in the lower stories than could be had with plump posts, and additional posts are inserted as the height increases. The assembling of the various parts is made in such a way that the trestle is easily raised piece by piece, and any piece can be removed without disturbing other parts of the bridge.

The floors are of 6 in. x 8 in. ties laid flat, and spaced 12 in. centre to centre. Inside and outside guard rails are used well notched down and bolted.

The timber was mostly cut and sawn by portable mills in the vicinity of the bridges. Red fir was used for all stringers, as it is by far the best timber for the purpose to be found in Montana. White pine is scarce, but Norway pine is more plentiful, and was used for posts and caps where fir was scarce.

Outside of those four large structures the smaller bridging and trestling was very light considering the rough character of the country. Fir timber was used for piling and stringers, and indeed it was used for all purposes when it could be had, which was not always the case.

The following is a partial list of the prices paid to contractors on this work :—

Solid rock	$ 0.90 to $ 1.00	per cubic yard.
Loose "	0.35 to 0.40	" "
Cemented gravel	0.35	" "
Earth, etc.,	0.16	" "
Embankment	0.16	" "
Tunnel	40.00	per lin. ft., stan. sec.
Tunnel Excavation	1.50	per cubic yard

The latter item was for enlarging the standard section to admit the timbering when necessary. Ordinary labour cost $1.75 to $2.00 per day.

The above prices will no doubt be considered low in comparison with prices paid for similar work elsewhere, and it may be here said that while there were no fortunes made by contractors, it is believed that all or nearly all competent men pulled through with more or less to their credit. As before stated, the most serious drawback was the expense of hauling in supplies; consequently, the maintenance of the camps was a serious drain on the profits of the work.

In regard to the cost of the work, the writer regrets having no estimates at hand, with the exception of 20 miles between Nyack and Coram. The heaviest mile in this 20 was 43,000 cub. yds., and the average cost of grading for the 20 was $14,200 per mile, but in this is included three miles of a flat where the work was light, and which considerably reduces the average from what it otherwise would be to 30,000 cub. yds. per mile; from Nyack to Summit the quantities were considerably heavier.

In conclusion, it may be stated that Mr. E. H. Beckler of Helena, Mont., was chief engineer of this work; and his organization of his staff was this: the whole work was divided into divisions in charge of division engineers. These divisions were subdivided into residencies in charge of resident engineers, who reported to the division engineer; and each residency was subdivided into sections of 6 to 10 miles, with an assistant engineer in charge of each, who reported to the resident engineer. The length of these divisions and residencies of course varied considerably according to the difficulty of the work in that particular locality.

Note added 1st March, 1894.

The drilling in both tunnels and open cuttings was done by hand there not being a steam or electric drill on the district. The tunnels were all in rock, and were excavated in this way. An upper heading of about 7 feet high was carried forward and kept several feet ahead of the bench. In this heading the timber plates were carefully set in varying lengths depending on circumstances, and the arch timbers and lagging put in place; after which the space around the arch was well packed with rock or cordwood. The sills and posts were placed afterwards according as the bench was removed to admit them. The specification called for rock packing around the timbers, but contractors preferred to use cordwood instead, and they were allowed to do so by furnishing the wood at their own expense. The wood is much more convenient for handling than rock, and probably as good in every way. The timbers were kept protected from getting shattered by shots and flying rocks by slabs of wood spiked to their faces; but occasionally a timber would get shattered so that it would be necessary to remove it, no matter what care was taken to protect it.

The bench was always kept up as close to the heading as possible, so that as much as possible of the material shot from the heading would fall clear of the bench, thus avoiding the labour of removing it. This item of clearing off the bench after a shot is often important.

About 16 drillers, or say 7 men, in the heading and 9 on the bench is as great a force as can be worked advantageously at one time. This was the force worked in No. 4 tunnel, which was worked from one end only. This was probably the most difficult tunnel to work, and working the usual hours per day the monthly progress was from 30 to 35 feet.

It was not always necessary to keep the timbering in place close up to the workmen. In one case the timber was not put in place until the excavation was completed; and had not the timber been on the ground and framed before the completion of the excavation, it might not have been used at all, as the roof turned out better than was expected. Material from tunnels was hauled out in ordinary carts.

Road-bed excavations were made 20 feet wide at grade and slopes 1 to 5 in rock and generally 1 to 1 in earth; but this latter was not strictly adhered to in all cases, however, for various reasons. There is a class of hard pan or gumbo in places that was found to stand well at a slope steep enough to keep it dry, but at a slope flat enough to allow it to get wet, it became semi-fluid, and ran down upon the road-bed. Again, there are places where a 1 to 1 slope would run into the mountain side, the natural slope being about the same. In these cases steeper slopes were used.

The width of embankment for 5 feet and under was 14 feet, and for over 5 feet, 16 feet wide at grade; slopes 1½ to 1, except along streams, where they were made 2 to 1 for rip rap or slope wall. (See Plate VIII.)

The primary difference between these two classes is that slope wall is supposed to be hand placed and rip rap thrown down more roughly.

Prices ranged about $1.00 per c. y. for rip rap, and $1.50 for slope wall.

A considerable part of the grading was done by stationmen in small contracts of a few stations each; and on account of the difficulty of getting heavy plant into the country, and cost of maintaining horses, much of the material was hauled out of cuttings in "Swede carts;" that is an ordinary dumping cart turned about to run backward, and hauled by men while one of them directs it from behind by a long pole which replaces the ordinary shafts. Others made "godevils" to run on rollers on a wooden track, while for short hauls others used trays to slide on greased poles. These "godevils" were hauled by horse power, of course.

Pile foundations were used where practicable to drive piles; and where they could not be driven on account of rock, cedar mud sills were set, or cribs were built and filled with rock. There were no special difficulties met with from the nature of the materials in foundations; of course it will be remembered that there were no heavy masonry piers or abutments erected. A detailed account of the foundations of the 4 large bridges cannot be given here with accuracy.

There were places on steep side hill where cribs or retaining walls were necessary to maintain the slope of embankment. These cribs were built of round logs according to the general plans (see Plate VIII), and were paid for at a stated price per lin. ft. of logs in structure when completed.

The track, a 68 lb. steel rail with 36 inch angle bars, with 6 bolts and hexagonal nuts, was laid with square joints and 16 ties to the rail. The rails were cut in 30 feet lengths with a number cut 29′ 6″ for inside of curves. These short rails had their ends painted at the mill, so they could be readily detected, and the tracklayers were furnished with a list of the curves and the number of short rails required for each. This was found to be an excellent plan to keep square joints, and the writer believes it to have been an original idea with Mr. Beckler, not having seen it elsewhere. The Holman track-laying machine was used, and the daily progress some days reached 160 stations. The rails, of course, were curved in the material yard and loaded on cars in the order required to fit the curves, without any assorting at the end of the track.

The ties used in the mountains were 7 inches thick, 7 inch face and 8 feet long, of fir and tamarac. The contract price was 25 cts. each, and, as stated, they were laid 16 to the rail, or 2,816 to the mile.

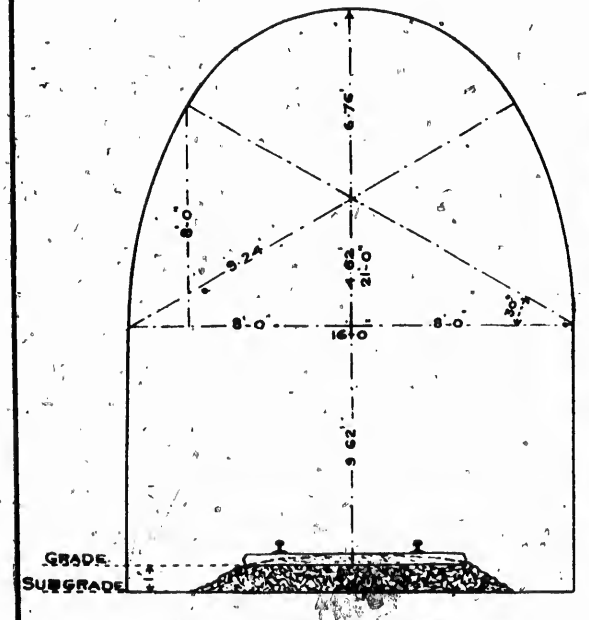
The grading was all done by Messrs. Shepard, Siems & Co., contractors of St. Paul. From Havre to the summit was done by contract, and from the summit west to the crossing of the Columbia River in Washington was done by the same firm on a percentage basis. The Railway Company thus retained an interest in the supply stores.

The prices given in this paper are those paid by Shepard, Siems & Co. to their sub-contractors west of the summit.

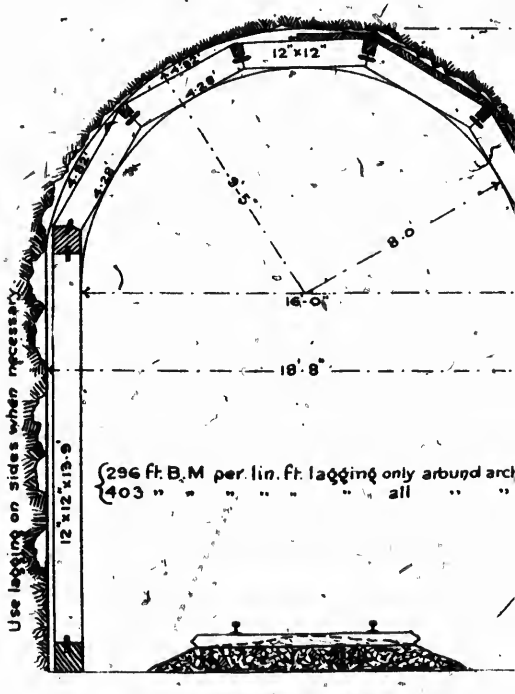
The timber was mostly furnished by the Boston & Montana Commercial Co. of Helena, and the structures were erected by Porter Bros. of St. Paul. Timber work was all done at a stated price per M. ft. B.M., but the writer is unable to give those prices with certainty.

GREAT NORTHER

STANDARD SECTIONS



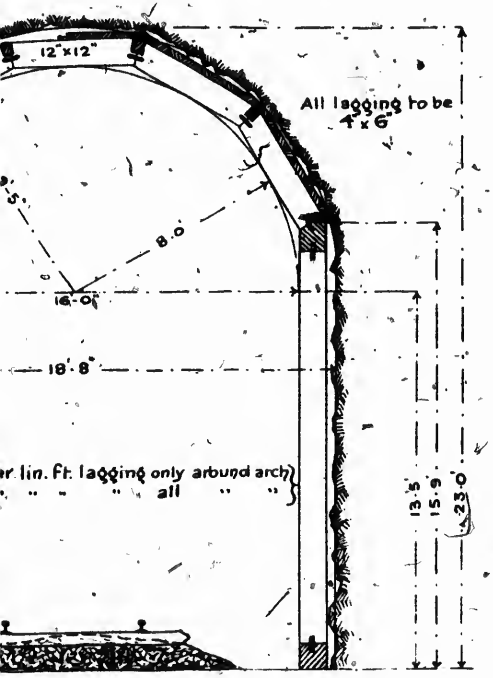
SOLID ROCK SECTION
11·07 Cub. Yds. per lineal foot.



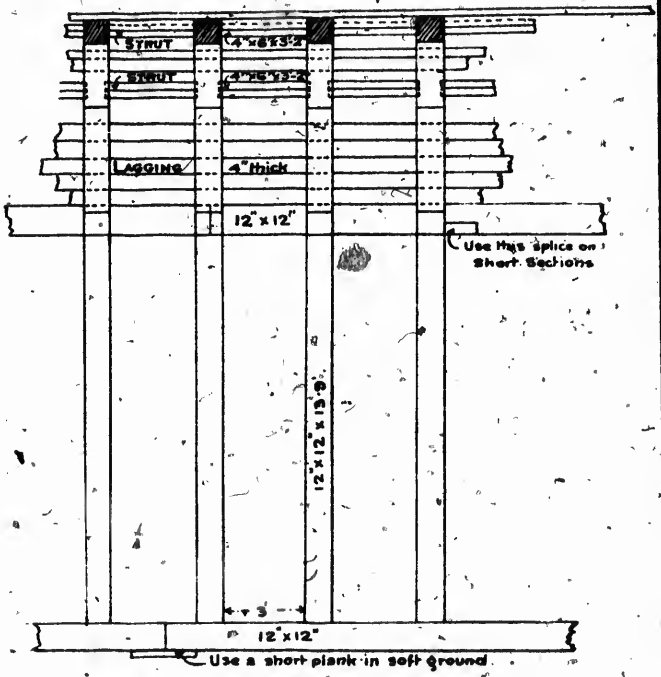
TIMBERED SECTION
14·585 Cub. Yds. per lineal foot

NORTHERN RAILWAY

SECTIONS FOR TUNNELS



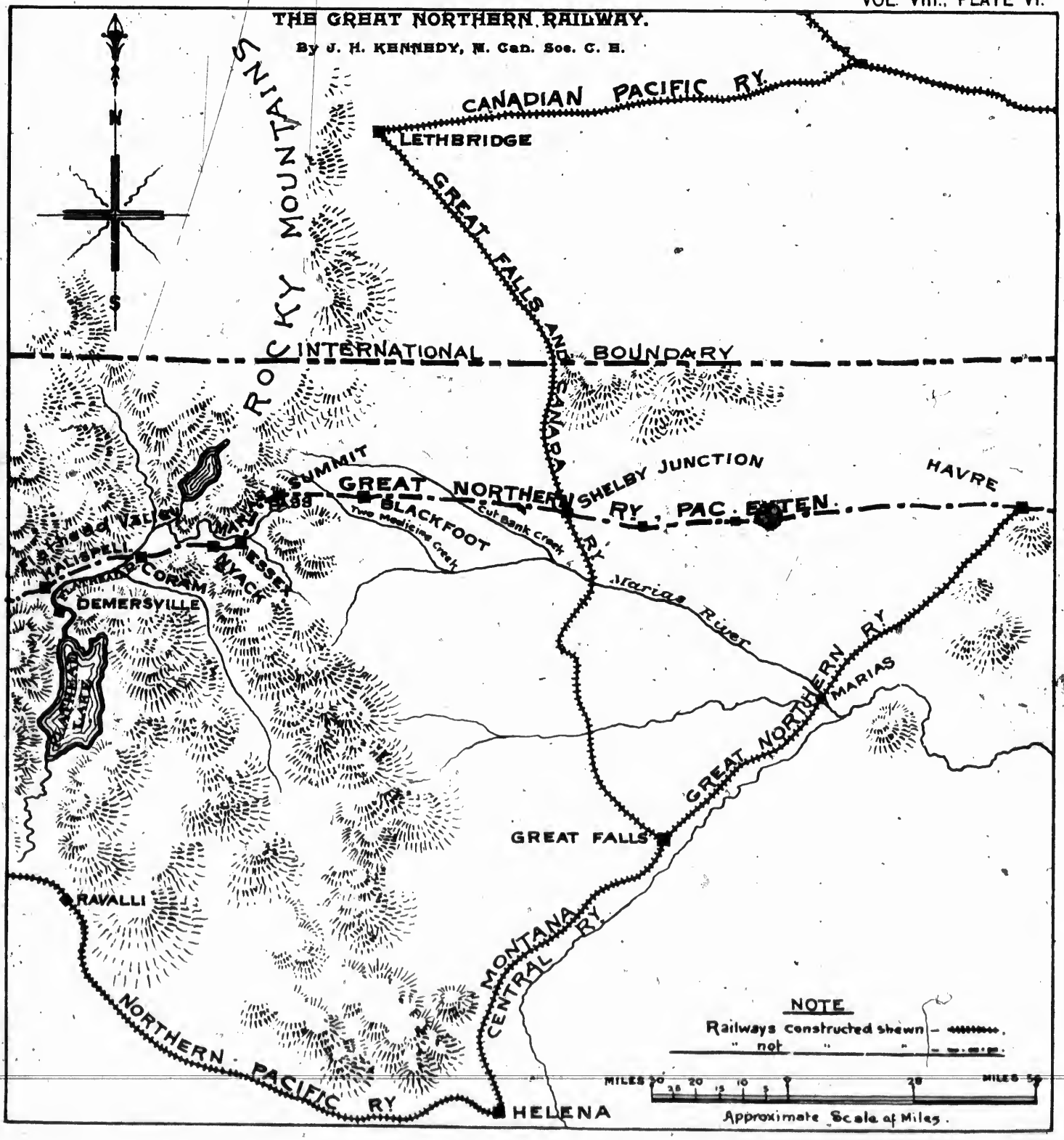
ERED SECTION
b. Yds. per lineal foot



LONGITUDINAL SECTION

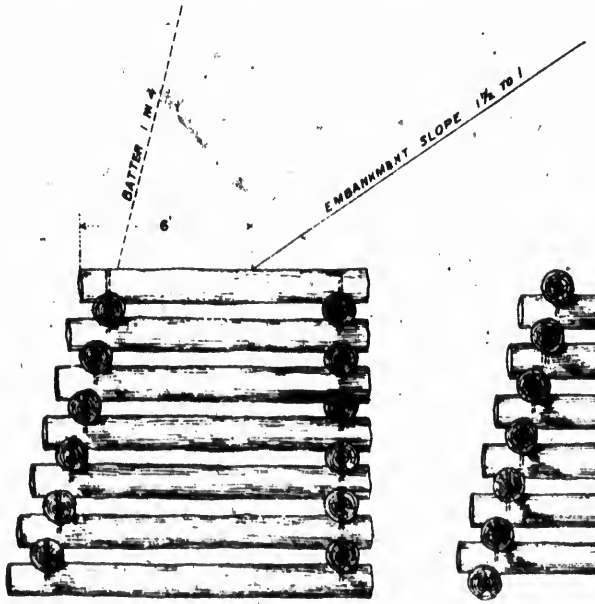
THE GREAT NORTHERN RAILWAY.

By J. H. KENNEDY, M. Can. Soc. C. E.

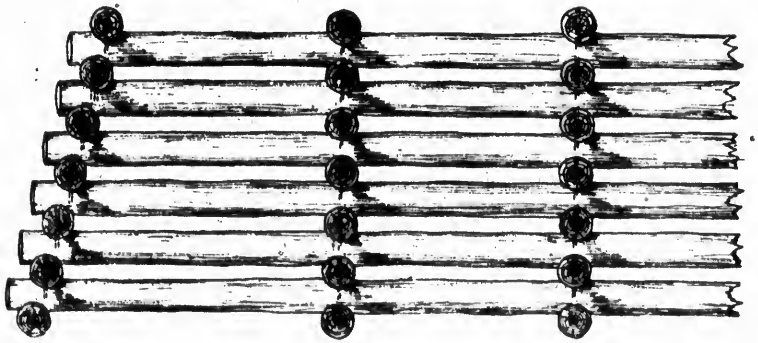


GREAT NORTHERN RAILWAY,
PACIFIC EXTENSION
BY JAS. H. KENNEDY, A. M. Can. Soc. C. E.

GENERAL PLANS.



· END · ELEVATION ·



· SIDE · ELEVATION ·

· END ELEVATI

Scale o

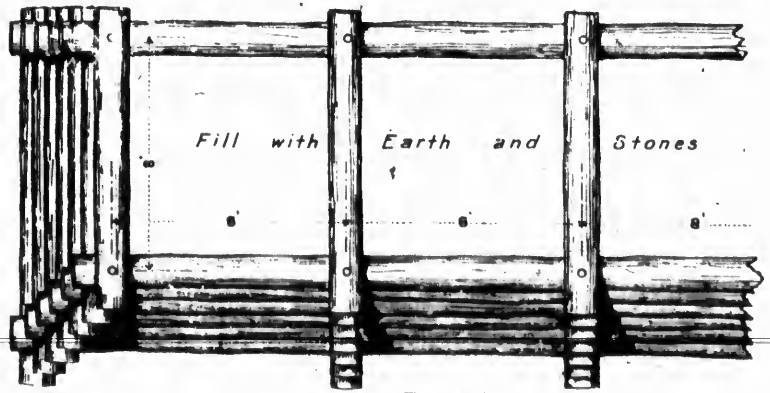
· PLANS · FOR · LOG · RETAINING · CRIBS ·

NOTE.

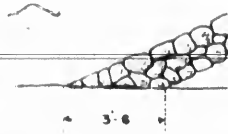
Tops of Cribs to be 6 Ft or more below Grade except along side of Streams where Grade is not sufficiently above High Water to permit this to be done.

Make width at Base so that Crib will be not less than 8 Ft. wide at the top.

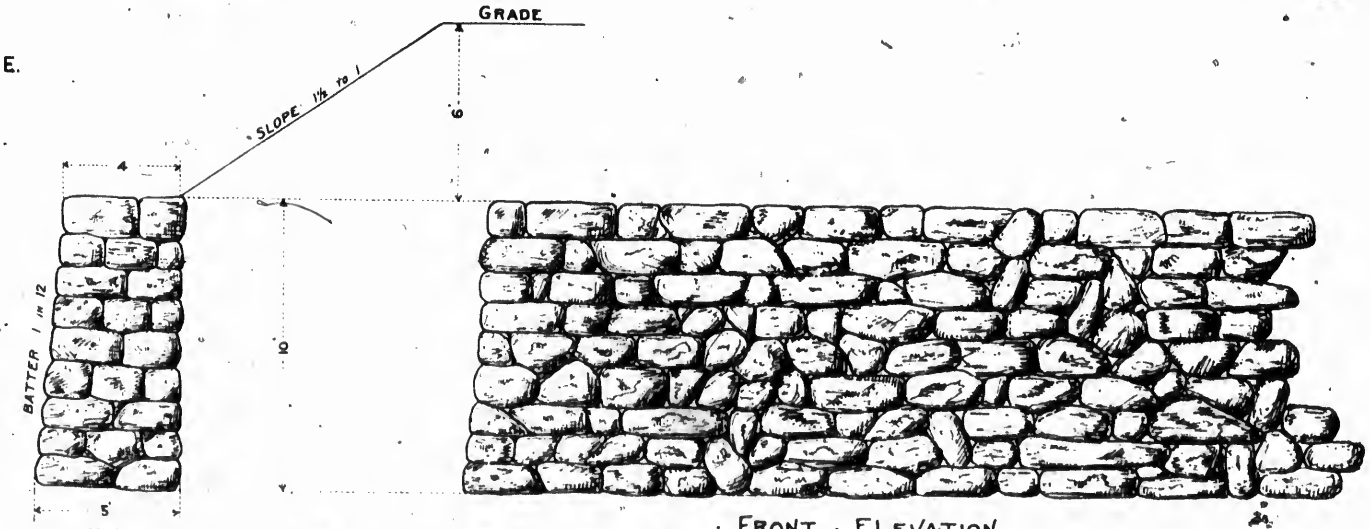
Logs to be secured with tree nails not less than 2" in diameter and 18' long.



· PLAN ·



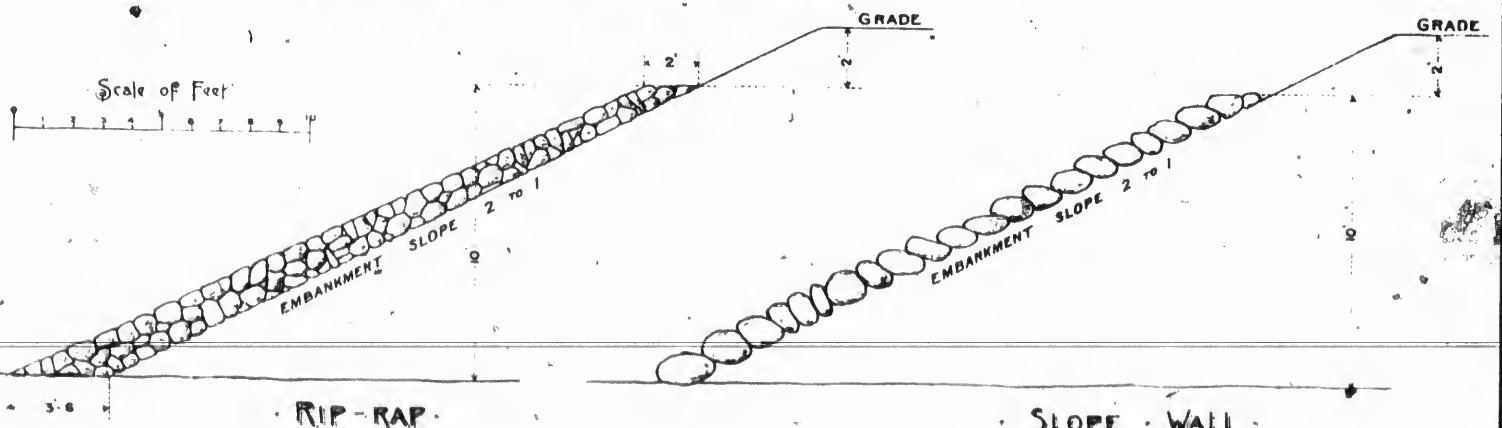
RAILWAY,
NSION
Can. Soc. C. E.
ANS.



END ELEVATION

FRONT ELEVATION

DRY LAID ROCK RETAINING WALL

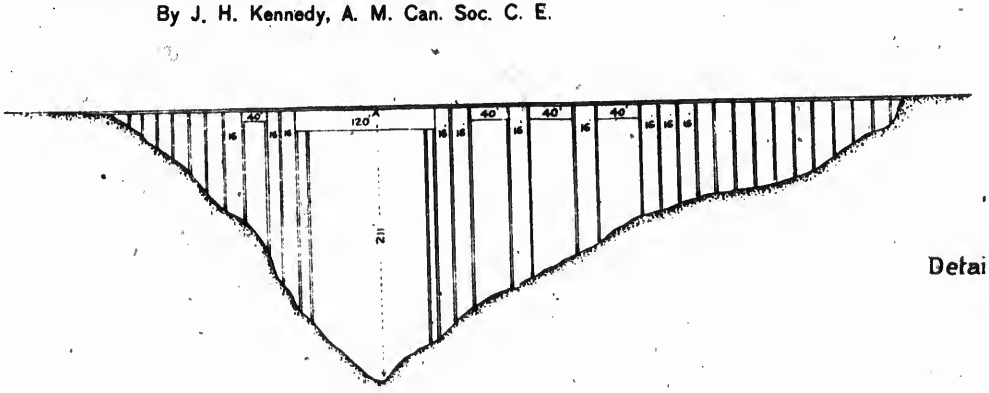


RIP-RAP

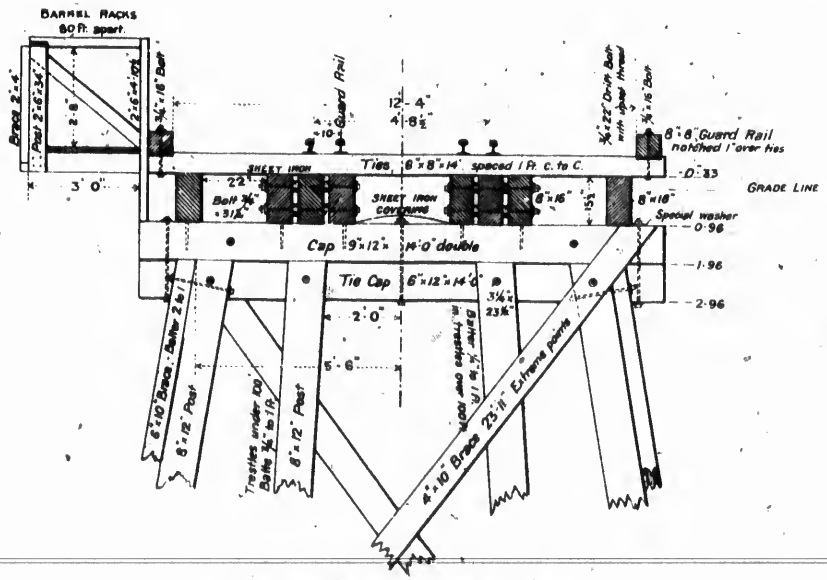
SLOPE WALL

THE GREAT NORTHERN RAILWAY,

By J. H. Kennedy, A. M. Can. Soc. C. E.

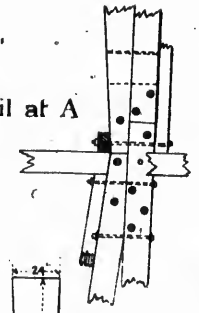


GENERAL PROFILE

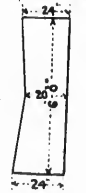


CROSS SECTION OF FLOOR

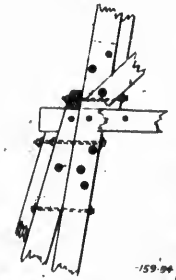
Detail at A



Packing Block at B.

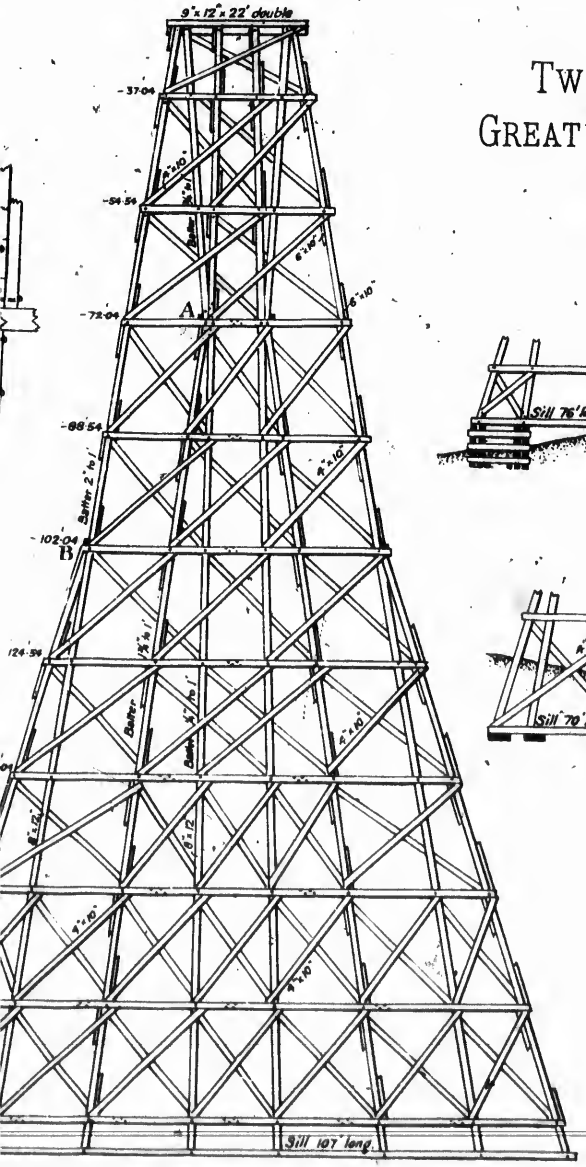


Detail at B.

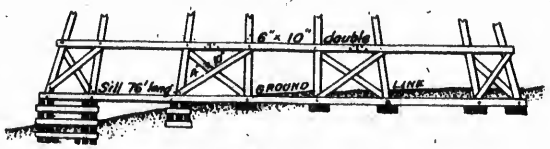


TOWER BE

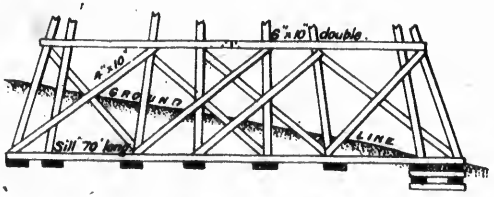
TWO MEDICINE BRIDGE
GREAT NORTHERN RAILWAY,



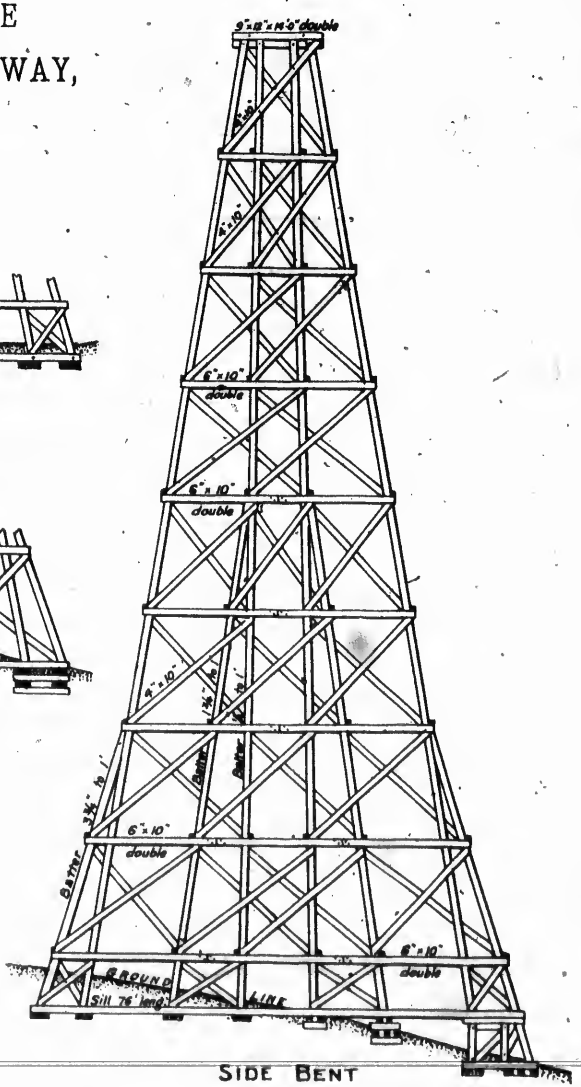
TOWER BENT



BENT Nº 18.



BENT Nº 25.



SIDE BENT
Nº 24.