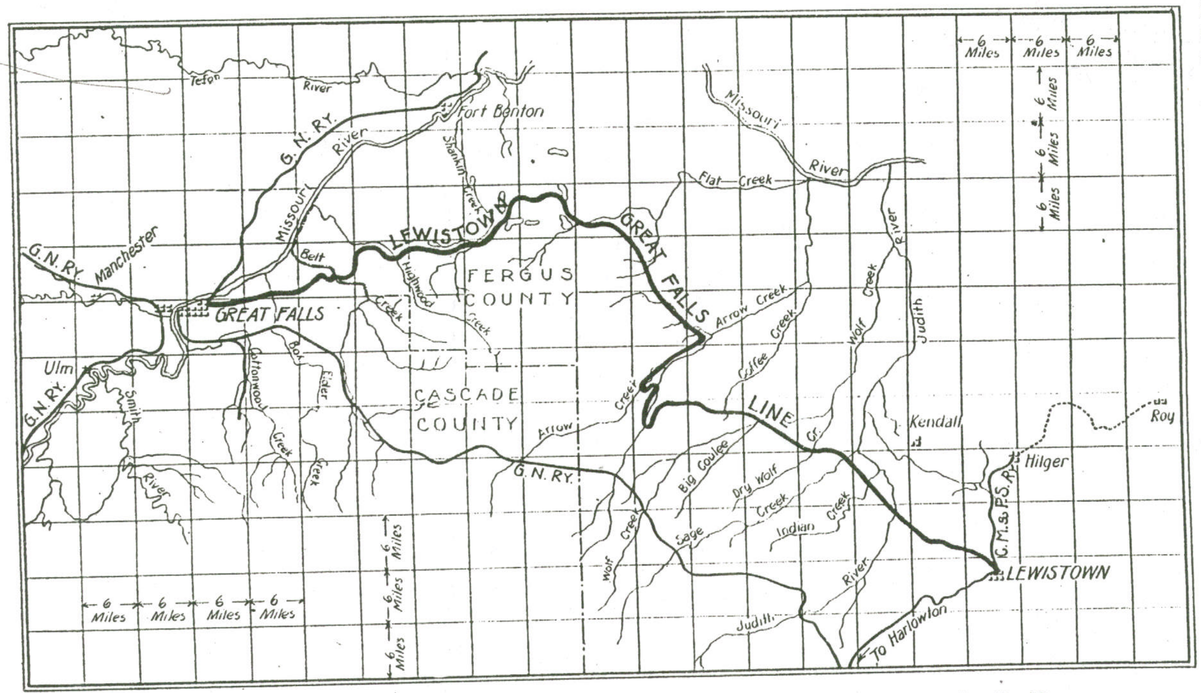


Fig. 1—Map Showing Route of Lewistown-Great Falls Line, C. M. & St. P. Ry.

crane is available, as the rock can be taken from the car and put in place by the crane. There is no kind of heavy work where a machine can be used that cannot be handled, with a locomotive crane with saving of time and labor.

Construction of the Lewistown-Great Falls Line of the C., M. & St. P. Ry.

I—Roadbed.

Almost constantly since the completion of its line to the Pacific coast the Chicago, Milwaukee & St. Paul Ry. has been engaged on the construction of one or more branch lines, with the result that the system beyond the Missouri river now has many feeders for the main line. An important work of this kind that is now in progress is an extension of the Harlowton-Lewistown branch, to Great Falls, Mont. The new line crosses the fertile Judith Basin country, and is 137 miles long. For purposes of construction, it is divided into three districts of about 45 miles each. These districts are in charge of district engineers, with headquarters at Lewistown, Square Butte and Great Falls. Each district engineer has four resident engineers under his charge. The resident engineers are located in camps along the line, with residences 10 to 15 miles in length each. The line was located in the winter of 1911-12, construction was commenced in June, 1912, and about 50 per cent of the work had been completed by March 1, 1913.

The accompanying map, Fig. 1, shows the route of the new line. The location was done by three parties. The original line, as projected, and surveyed in 1910, ran considerably north of the one on which construction is now being carried out, and was about 20 miles longer.

Starting out of Lewistown, the line runs along and down Big Spring creek, about 9 miles, to Cottonwood creek, where a joint crossing is made with the Great Northern Ry. on a timber trestle (Fig. 3) containing about 1,000,000 ft. b. m. of timber. The length of this trestle is 1300 feet and the hight 80 feet. After crossing this creek, the line runs in an almost true northwest direction 12 miles, crossing Judith river and Indian creek on high steel viaducts, to Sage creek. This 12 miles is over comparatively smooth country, but cross drainage necessitates the construction of long concrete culverts and high embankments, making the work more expensive than a cursory examination of the country might indicate. The crossing of Sage creek necessitated about 2 miles of supported line along badland formation on the east side of Sage creek, making heavy cuts and fills to the crossing of this creek. Sage creek is crossed on a high viaduct. The maximum hight is 165 feet and the length 1800 feet.

West of Sage creek the line is supported along formation similar to that on the east side, to the tunnel. This tunnel is 2000 ft. in length and pierces the divide between Sage and Dry Wolf creeks. The line then continues in a generally westerly direction, crossing Running Wolf and Coffee creeks, making rolling grades to a point about 45 miles from Lewistown on the so-called Arrow Creek bench. At this point the line begins to descend a 1.5 per cent grade with side-hill development along badland formations making necessary heavy cuts and fills and following the drainage of Surprise creek for 9 miles. To make the descent the line loops up Surprise creek for 2 miles, then, crossing the creek, descends on the opposite side. The line makes a total drop of 800 feet from Arrow Creek bench to the so-called "Big Sag." This portion of the line shows some interesting features in location and the badland formations on both sides of Arrow creek exhibit geological freaks of various kinds.

About 61 miles from Lewistown the line leaves Arrow creek and ascends a feeder of the same into the "Big Sag." The line then runs in a more northerly direction, following the Sag, which makes comparatively easy construction for 50 miles to Highwood creek. The Sag follows along the base of the Highwood mountains, on the north side of same. The line then descends Highwood creek for about 4 miles, thence on ascending grade on heavy side-hill support, over a divide for 4 miles to a point on Belt creek. Here is encountered about 6 miles of extremely heavy work, developing down the slopes of Belt creek with heavy curvature and deep cuts and fills. Four tunnels, with an aggregate length of 2700 ft., and two viaducts, crossing Belt creek and Red coulee, are necessary. Several long concrete culverts, with the corresponding deep cuts and fills, make the portion of the line from the point where Belt creek drainage is encountered to Great Falls quite expensive. The location along Belt creek is also an interesting piece of work.

The territory crossed by any route following close to an air line from Lewistown, on the eastern rim of the Judith Basin, to Great Falls, on the Missouri river, 100 miles to the northwest, must cross at right angles practically all of the drainage

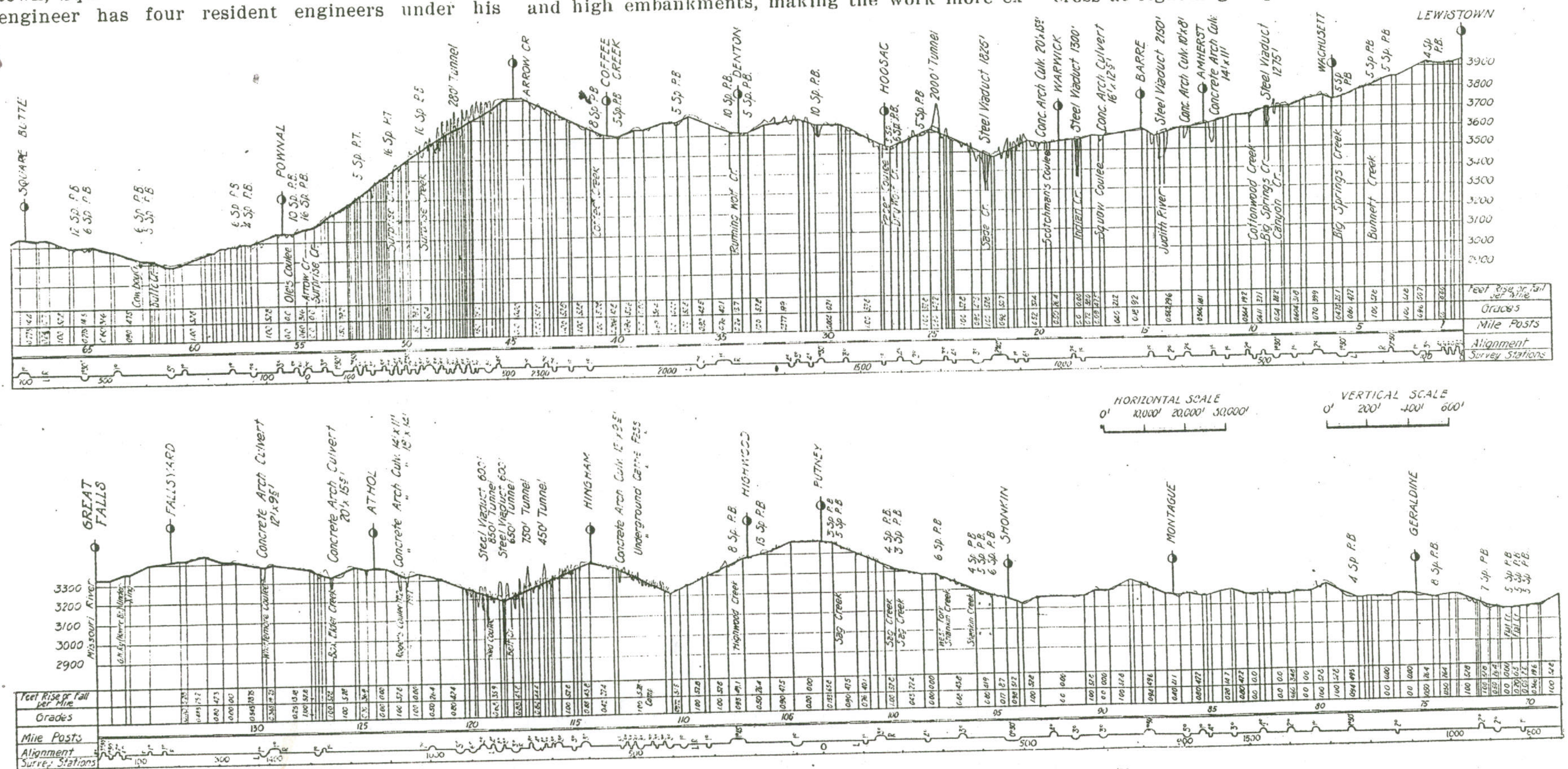


Fig. 2—Grade Profile, Lewistown-Great Falls Line, C. M. & St. P. Ry.

Fig. 3—Joint Timber Trestle, C. M. & St. P. Ry. and Great Northern Ry. Over Big Spring Creek, at Mouth of Cottonwood Creek.

that flows into the Missouri river between those two points. The character of the country varies from the practically level benches to semi-mountainous badlands. The high-level benches are often bordered by creeks which run in deep ravines, the banks of which are of badland formation. Arrow creek, by way of which the bottom of the Sag is reached, is 800 ft. below the bench a mile to the east. A loop of six miles in Surprise creek, on a 1.5 per cent grade, affords a line into this avenue at a loss of approximately 14 miles in distance.

The maximum grade (eastbound) is 1½ per cent for 8.6 miles; for the balance of the line the maximum is 1 per cent. There is a helper grade up Surprise creek to the Arrow Creek bench. The maximum curvature is 8 deg. 2 min.

The tunnel sections are 16x21½ ft., inside the concrete lining. All of the tunnels will be lined, requiring something like 20,000 cu. yds. of concrete. The Surprise Creek tunnel is on tangent and the spiral of a curve, and is 250 ft. long. It it through blue shale. The Belt Creek tunnels are 450, 750, 650 and 850 ft. in length, respectively, or aggregat-

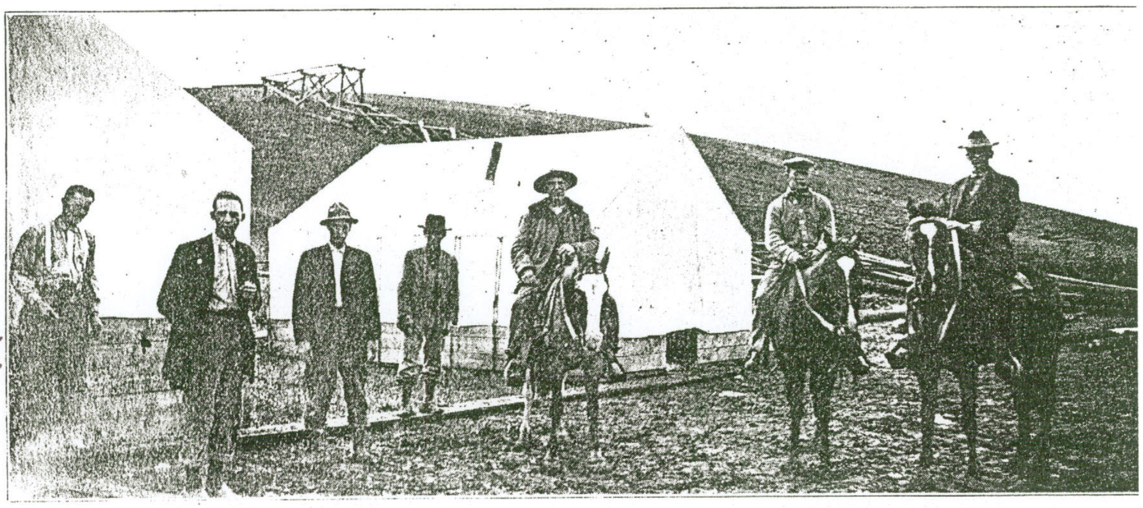


Fig. 4—Engineers' Camp at Box Elder, Lewistown Great Falls Line, C. M. & St. P. Ry.

ing in the center core; then, in turn, the full tion of heading was taken out for one set of t bers, which were placed, packed and lagged bef further excavating was done.

Owing to delays in getting out the west appro cut, and in order to push the work, two shafts, 6 ft., were sunk for the purpose of drifting the he ing. Shaft No. 1 is 62 ft. deep and shaft No. 110 ft., the two shafts being 475 ft. apart.

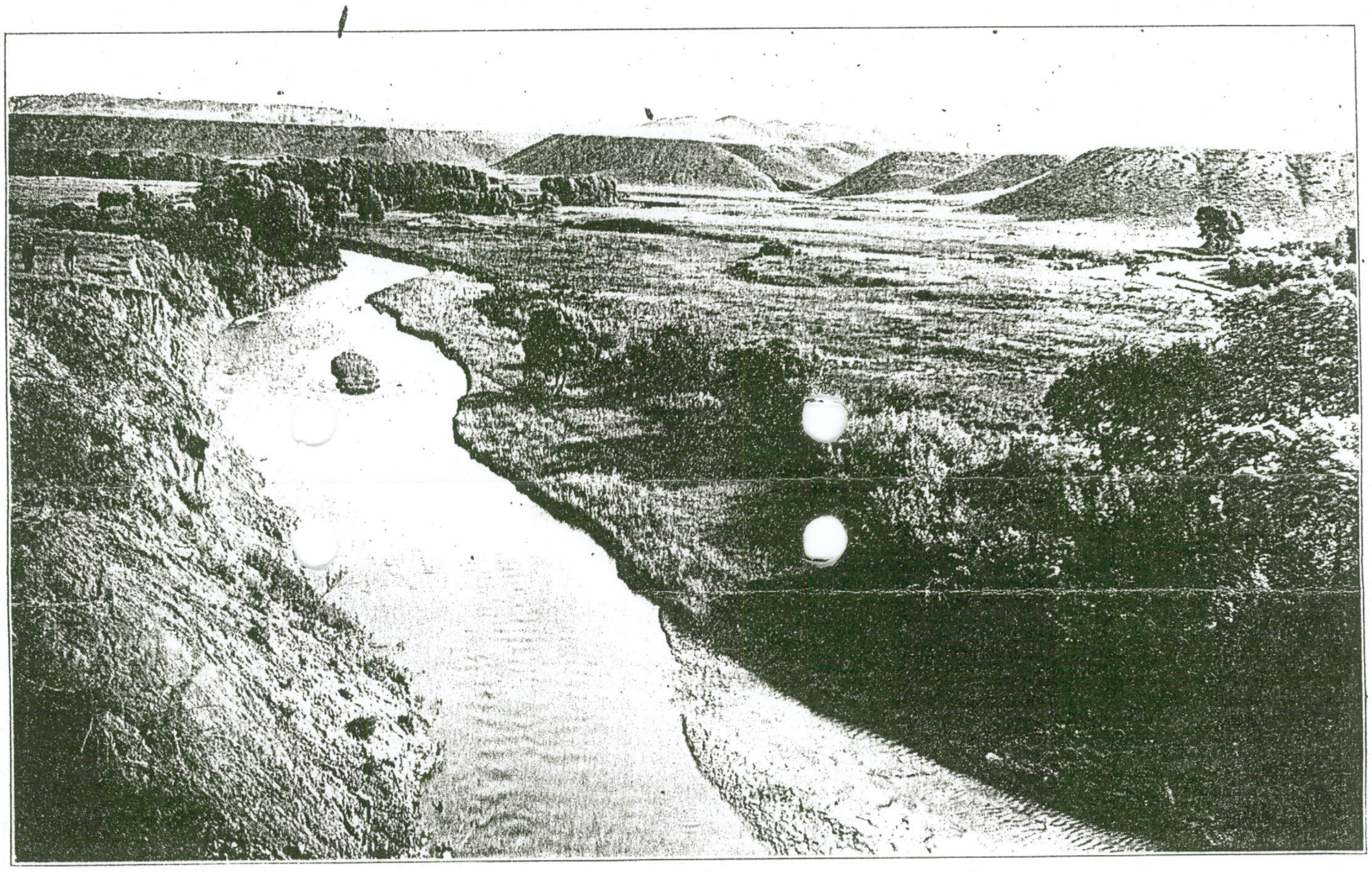


Fig. 5—General View of Judith River Country, Lewistown-Great Falls Line, C. M. & St. P. Ry.

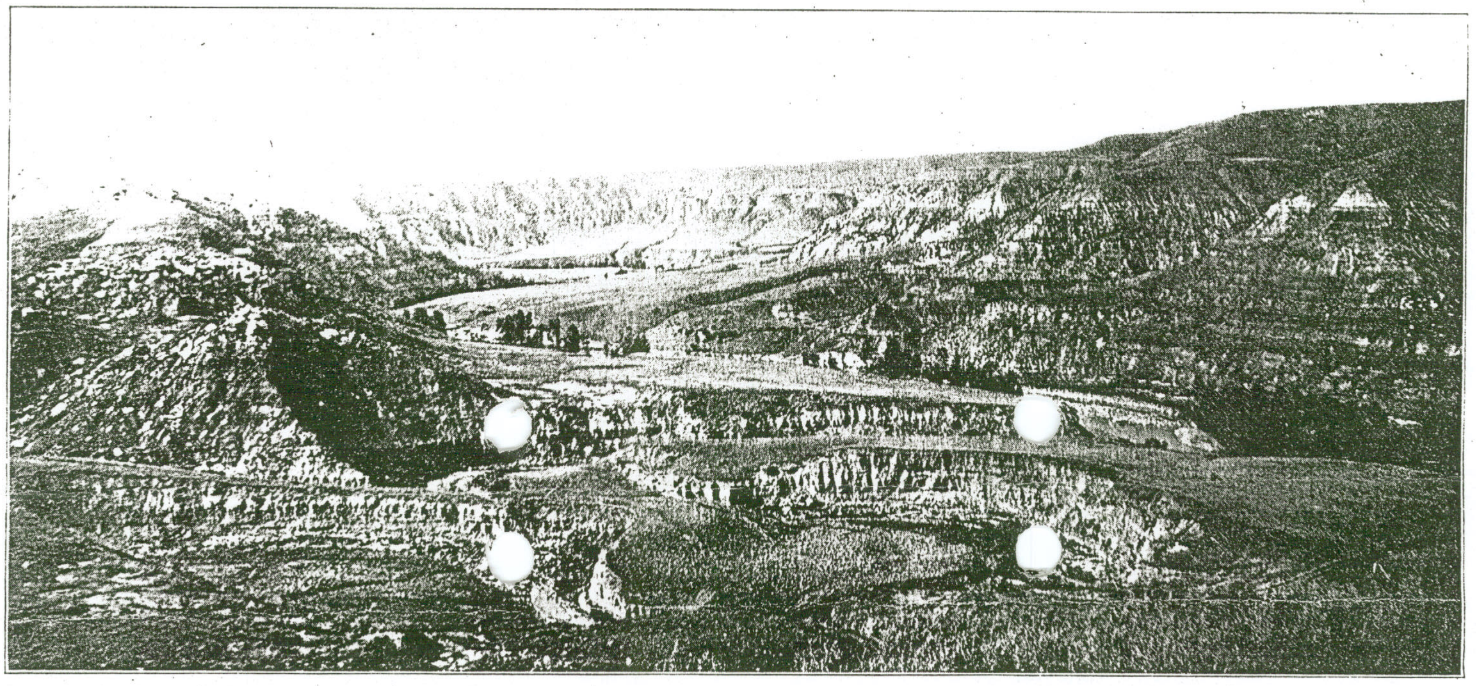


Fig. 6—Junction of Beet Creek and Red Coulee, Lewistown-Great Falls Line, C. M. & St. P. Ry.

alignment was carried by the method of two 18-pound plumb bobs suspended by No. 24 piano wire in oil. The material was taken out of the shafts by gasoline hoists.

Some little water was encountered, and this, together with the tendency of the material to air-slake, made it necessary to use lagging and packing for the full tunnel section. The heading was packed with slabs, while the sides was packed with rock and dirt—anything, in fact, to fill up all the voids.

Extensive use has been made of cast iron pipe for culverts. Practically all of this is 3 ft. in diameter, and it was hauled out ahead of the grading on wagons, the average haul being 16 miles. On District No. 1, 2400 lineal feet of cast iron pipe, 2100 ft. of corrugated pipe and 2000 ft. of concrete pipe were used, the last named being 4 to 16 ft. in diameter. On District No. 2, 2000 lineal ft. of cast iron pipe, and on District No. 3, 3500 lineal ft. of cast iron pipe were used in the culverts.

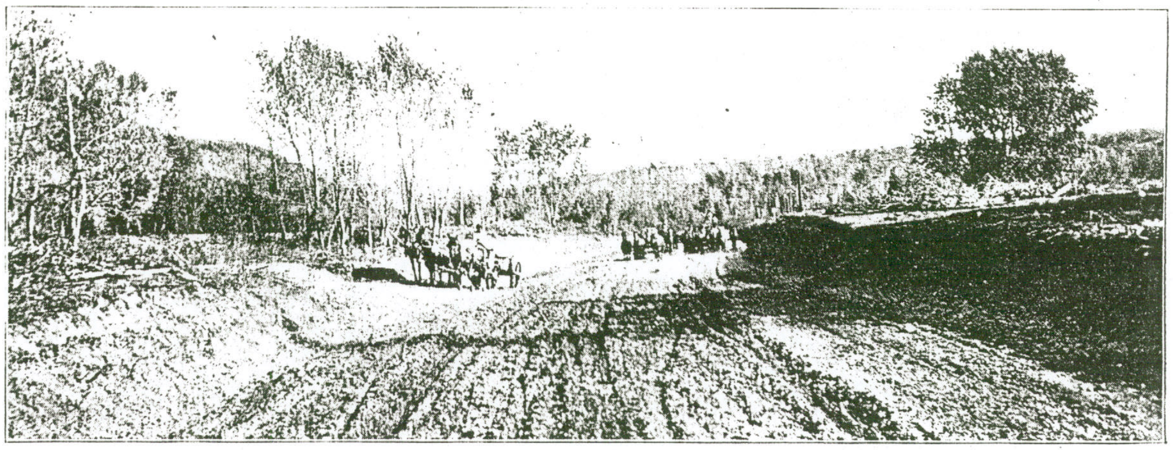


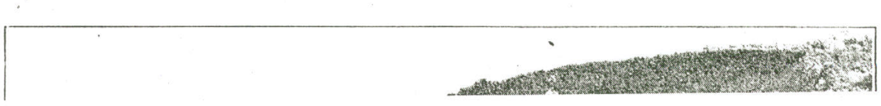
Fig. 7—Grading in Judith River Channel Change.

On District No. 1 there is a steam shovel cut measuring 80,000 cu. yds., in hardpan, and one measuring 170,000 cu. yds. in blue shale. The highest fills on this district are between Lewistown and Sage creek, and three of them stand 108 ft., 90 ft. and 86 ft. high, respectively. On District No. 2 in the Surprise creek breaks, there are fills 92 ft., 78 ft. and 75 ft high. On this district there is a cut involving 75,000 cu. yds. of shale and hardpan excavation. On District No. 3 there are fills 90 to 150 high, in the Belt Creek territory, and there is a cut involving 120,000 cu. yds. of hardpan and another involving 130,000 cu. yds. of hardpan excavation, in the Box Elder creek territory. The above mentioned are only the maximum cuts, there being many other cuts involving 40,000 to 60,000 cu. yds. of excavation each. The approximate yardage on the entire line will reach 5½ million.

The "Big Sag" is a unique formation, extending from a point on the Missouri river, about 25 miles below Great Falls, in a southeasterly direction to the foothills of the Highwood mountains, 30 miles distant; then in a general easterly course to Arrow creek the waters of which follow in its path for 12 miles, where it breaks away again to the east about 10 miles to the Judith river, which follows in its wake to within 6 miles of the Missouri, where it again leaves the channel to the left and opens into the Missouri river at a point approximately 70 miles from where it began. A number of lakes are situated in the bottom of this sag, covering from an acre to two sections of land and completely occupying all of the valley from bank to bank. It is the belief of the geologists that this section of country slipped away and settled toward the Missouri river, leaving a great fissure in the surface that has been thousands of years in filling up. While several of the principal streams of the watershed composed by the Moccasin, the Snowy Belt and the Highwood mountains follow this sag for short distances, no stream of any importance empties into or heads in its path.

The track is being laid with 75-lb. rails on sawed ties, 3000 to the mile. The ballast is gravel, which is found in fair quantity along the line, and about 3600 cu. yds. of this material will be used per mile of track.

The concrete work is now nearly finished. The



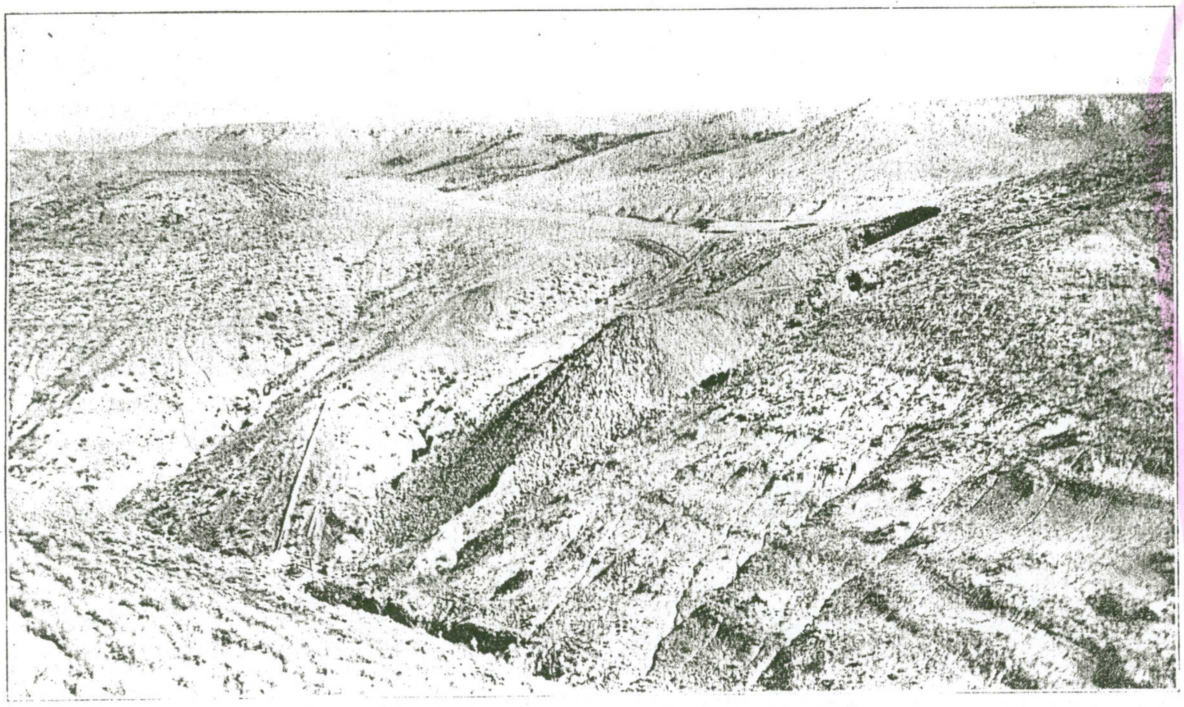


Fig. 10—Another View of Carlson's Cut, West End.

Judith river viaduct has been completed and track has been laid to Indian creek, 20 miles from Lewistown. Track laying is about to be begun on the Great Falls end. The Belt creek and Red Coulee bridges will be erected as the track laying reaches them, and it is expected to have them completed before they are reached by the tracklaying from the east.

This line is being built under the general supervision of Mr. C. F. Loweth, chief engineer, C., M. & St. P. Ry. At the time the line was run and construction commenced, the work was in gene[illegible] charge of Mr. E. O. Reeder, chief engineer, Chic[illegible] Milwaukee & Puget Sound Ry., but by a subsequent change the jurisdiction of the C., M. & St. P. Ry. has been extended to the Pacific coast. Mr. A. G. Baker, division engineer, was in direct charge of the three locating parties, under Messrs. C. Jackson, W. R. Felton and Mr. MacVicar, and has had charge of the grading and tunnel work. The bridge and concrete culvert work, which have been in charge of Mr. F. J. Herlihy, assistant engineer, will be described in a later article.

Rail Failures and Their Causes.*

By M. H. Wickhorst.

Recent years have been active ones in the matter of investigations of rail failures by the railroads, the rail manufacturers and public service bodies, and it is proposed in this paper to consider our present information concerning the nature of the failures and their causes.

From the standpoint of the visible condition of the failed rails most of the rail failures may be divided into there classes, as follows:

1. Crushed and split heads;
2. Broken rails (square and angular breaks);
3. Broken bases (crescent breaks)

In addition to these, there are other failures occurring in smaller numbers, such as "cracked webs" (horizontal longitudinal cracks through the web) and "transverse fissures" (transverse internal cracks in the interior of the head).

Statistics concerning the rail failures occurring in the United States have been published for several years by the American Railway Engineering Association, and in Table I are given a few figures covering rail failures for the year ending October 31, 1911.[1] The tons are long tons of 2240 lb. and represent the tons of new rail laid.

It will be noticed from this table that the failures in 1911 per 10,000 tons of new rail laid were 31.0 for Bessemer steel, 20.7 for open-hearth steel, and the average of all rails was 29.0.

On the basis of number of rails, there was one failure per 891 Bessemer rails, one failure per 1234 open-hearth rails, and one failure per 941 rails of both steels. This suggests that open-hearth steel is less liable to failure than Bessemer steel, but on the other hand it is probably true that the open-hearth rails were in general of more recent manufacture and probably also contain more of the newer sections. The table cannot therefore be said to be conclusive in its indications in this respect.

The table shows us that there was one failure per 941 rails, but we seem not to have general information of all the failures occurring during the full period of service of a lot of rails. Assuming, for the purpose of forming some idea of the order of magnitude of the average total failure[illegible] a lot of rails, that the average life of rails is 8 [illegible]rs, the total failures per lot of rails would average about one failure per 118 rails or something under 1 per cent.

TABLE I.—Rail Failures in 1911.

	Bessemer	Open-Hearth	Total
Tons of rails represented	10,088,706	2,600,008	12,688,714
Number of rails based on 30-ft. lengths	27,866,348	6,622,736	34,489,084
Number of failures:			
Broken	8,165	1,786	9,951
Head	17,761	2,260	20,021
Web	2,450	515	2,965
Base	2,898	806	3,704
Total	31,274	5,367	36,641
Failures per 10,000 tons:			
Broken	8.1	6.9	7.9
Head	17.6	8.7	15.8
Web	2.4	2.0	2.4
Base	2.9	3.1	2.9
Total	31.0	20.7	29.0
Percentage of Failures:			
Broken	26	33	27
Head	57	42	55
Web	8	10	8
Base	9	15	10
Total	100	100	100
Number of rails for each failure	891	1,234	941

While the American Railway Engineering Association statistics above referred to indicate an improvement in the general failure performance from year to year in the last three years that they have been kept, we still hear of occasional lots rolled in recent years that give very poor service. As an example may be mentioned a lot of 2500 tons of 80-lb. A. S. C. E. Bessemer rails rolled in September, 1909, and placed into track in October, 1909. Up to May, 1912, or in a period of service of 2½ years, there were 510 failures classified by the trackmen as follows:

Crushed head and flow of metal	243
Split head	93
Split web	89
Broken	81
Broken base	4
Total	510

This would be 2040 failures per 10,000 tons; or figured on the basis of 30-ft. lengths, there would be one failure in each 13.7 rails in 2½ years from the time the rails were put into service. I am advised that since May, 1912, other rails have been removed from track and still others at this writing (March, 1913) are developing a condition that will necessitate their removal. Thus far about seven per cent of this lot of rails have been removed from service on account of failures, mostly of the head, and it seems probable that finally the number may amount to ten per cent or more. This type of failure, as will be explained, is to be attributed to the interior condition of the ingot from which the rail is rolled, described as segregation and its accompanying conditions.

Crushed and Split Heads.

Head failures are the most numerous and most of these may be described as crushed or split heads. This failure consists of an internal crack in the head running lengthwise of the rail anywhere from a foot or two to several yards in length. The external appearance may show only a crushing of the head; but when broken, the rail will show a crack in the interior of the head running lengthwise of the rail. This kind of failure is confined almost entirely to metal showing considerable internal segregation of carbon, phosphorus and sulphur, attended more or less with laminations and slag seams.[2] Under wheel loads, the top of the head flows sideways and if the interior metal cannot likewise flow sideways due to internal flaws or due to brittle material in the interior, it develops a crack which grows and later forms a split head, the crack generally coming to the surface at the underside of the head at its junction with the web. Frequently the crack extends downward into the web and comes to the surface at the side of the web, and then the trackman is apt to report the failure as a web failure, whereas in reality it was a head failure. Split heads may thus be said to be due to lack of transverse ductility in the interior of the head, due mostly to segregation.

Broken Rails.

The next largest class of rail failures is that called "broken" rails, including square and angular breaks; that is, the rail breaks through the whole section more or less vertically. This type of failure is most predominant in winter, particularly in severely cold weather, and may be termed "winter disease" of rails. The severe winter of 1911 and 1912 brought out a very abundant crop of such failures on the northern roads. An examination of the fractures of such rails shows that the fracture is upward through the section; that is, it

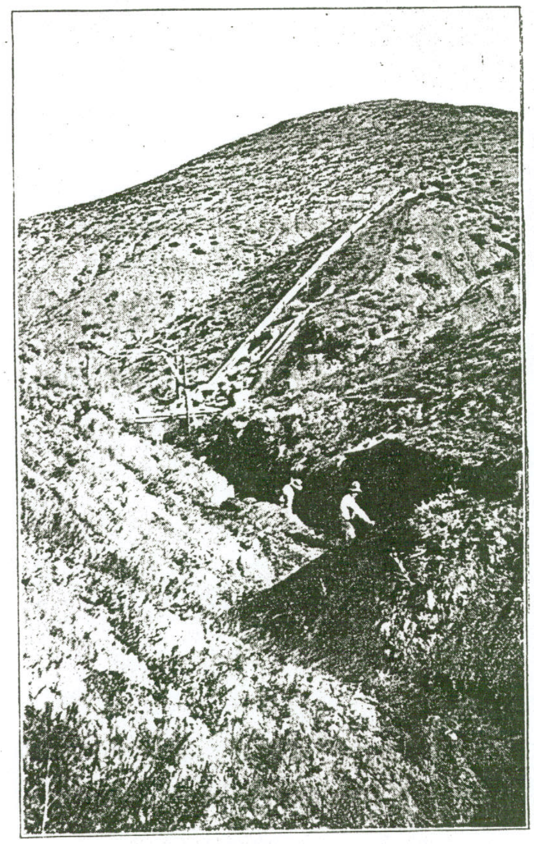


Fig. 11—Excavating for Pipe Culvert, Lewistown-Great Falls Line.

*From a paper presented at the annual meeting of the American Society for Testing Materials, Atlantic City, N. J., June 24-28, 1913.

[1]Bulletin No. 147, Am. Ry. Engrg. Assoc., Vol. 14, p. 392 (July, 1912). Also Proceedings, Am. Ry. Engrg. Assoc., Vol. 14, p. 392 (1913).

[2]See Proceedings, Am. Ry. Engrg. Assoc., Vol. 12, Part 2, pp. 469-493 (1911). See also "Studies of Failed Rails," by W. C. Cushing, Ibid, pp. 2[illegible]0-384.