Scientific American.

ESTABLISHED 1845.

MUNN & CO., Editors and Proprietors.

PUBLISHED WEEKLY AT
NO. 37 PARK ROW, NEW YORK.

O. D. MUNN. A. E. BEACH.

NEW YORK, SATURDAY, MARCH 20, 1880.

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Price 10 cents. For sale by all newsdealers.

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THE ST. GOTHARD RAILWAY TUNNEL.

The junction of the northern and the southern sections of the St. Gothard tunnel was accomplished on the morning of February 29, thus bringing to successful issue the boldest and most difficult engineering work of the kind hitherto attempted.

The St. Gothard group of mountains comprise that part of the Alpine range in South Central Switzerland, directly north of the valley of Lake Maggiore, and separating the railway system of Switzerland from that of Northern Italy.

The project of tunneling Mount St. Gothard was a necessary consequence of the tunnel through Mont Cenis. Until that time most of the traffic and travel between Italy and Switzerland—in other words, a large part of the overland commerce between England, Belgium, Northeastern France, Western and Central Germany, and Northern Europe generally, on the one hand, and Italy on the other, and the Levant, as reached through the Italian ports—was carried on through Switzerland. The three great roads over the Swiss Alpine passes, the Simplon, the Splügen, and the St. Gothard, monopolized by far the larger part of this important trade. This monopoly was broken up when the Mont Cenis tunnel was completed in 1870, the bulk of the traffic and travel being thereby diverted through Western Italy, by way of France, to the inconvenience and loss of Northern and Central Europe.

Switzerland and Germany especially felt the need of restoring a more direct line of transit. The Simplon route was rejected because, like the Mont Cenis route, it would be directly tributary to France. The Splügen pass was less difficult than the St. Gothard, but the road leading to it must pass along the upper Rhine, in dangerous proximity to the Austrian frontier. The favorable geographical situation of the St. Gothard route, in the heart of Switzerland, more than offset, it was thought, its engineering difficulties, and it was therefore adopted. The entire length of the costly railway line, of which the St. Gothard tunnel forms a part, is 151 miles, 17 per cent of it being tunnels, and 1 per cent bridges and viaducts. The main tunnel is about 9½ miles long. There are twelve other long tunnels, ranging between 1,106 and 2,027 yards, and aggregating nearly ten miles in length; five tunnels between 220 and 550 yards in length; and twenty-five tunnels between 110 and 220 yards long. In all, there are fifty-two of these subsidiary tunnels, having a total length of 16 miles. The line is also carried over sixty-four bridges and viaducts, the longest, at Cadenazzo, in Tessin, consisting of five spans of 55 yards each.

The main tunnel traverses Mt. St. Gothard between Goeschenen on the north side and Airolo on the south. The contract for its construction was awarded to M. Louis Favre, of Geneva, August 7, 1872. The work was begun at Airolo the following month, and at the other end in November. The time set for the completion of the great task was eight years—six months more than the time actually employed.

Airolo station is 3,757 feet above the level of the sea, and Goeschenen 3,639 feet. The tunnel runs straight between these two points, except for 158 yards at the Airolo end, where a curve connects the tunnel with the station. The tunnel has been constructed for two lines of way, 4 feet 8½ inches gauge, the contract calling for a cutting of horseshoe form, 19·68 feet high by 24·93 feet wide at the level of the sleepers, and 26·24 feet at the springing of the arch, 6½ feet above the sleepers. The arch is a complete semicircle of 4 meters radius. The sides are curved to a radius of 33·13 feet. Where the rock was solid the tunnel was cut to the exact section without masonry.

The line of the tunnel rises from both ends to a summit level 197 yards in length; the northern gradient, for 8,128 yards, rising at the rate of 1 in 172; the southern gradient, 1 in 1,000, for 7,970 yards.

Before the work was begun, Professor Fritsch made a careful study of the strata to be pierced, and expressed the opinion that the principal mass to be traversed consisted of gneiss rich in mica; mica schist, gneiss, and hornblende-schist. These, he believed, extended through the mountain in the form of a fan, and he figured the amount of each as follows:

	Meters.
Granite gneiss, more or less homogeneous	2,200
Gneiss, more or less schistous	450
Crystalline limestone and gray marble	350
Micaceous schist passing into gneiss	1,300
Gneiss rich in mica passing into mica schist	6,600
Mica schist with hornblende	1,600
Gneiss more or less schistous	270
Mica schist, with veins of quartz	800
Hornblende schist	1,250
Dolomite, gypsum, etc.	100

The nature of the rock met throughout went, in the main, to justify the Professor's prophecies. The material taken from the opposite ends differed widely. At the north end a layer of very hard rock was first met; hardly any water came from the roof, and but little timber was needed. At the southern extremity, on the contrary, the dominant rock was mica-schist, with numerous fissures, through which water leaked into the tunnel in great quantities. At one time it rushed in at the rate of 420 gallons per minute, and brought with it masses of *débris*. Later on, when beds of clay were struck, it rushed in at the rate of 2,640 gallons per minute. One hundred and eighty yards in a spring was met, which delivered 1,000 gallons a minute, and stopped the work for several days. The leakage kept varying from time to time, and at that side always giving much trouble to the workmen.

The headings were about eight feet square, giving frontal areas of sixty-seven and a quarter square feet. For the first half year they were driven by hand; after that, mechanical perforators, operated by compressed air, were employed. Full descriptions of the various devices of this sort, adopted during the progress of the work, with much detailed information touching the methods of working, rates of speed, cost of excavation, and so on, will be found in the several volumes of the SCIENTIFIC AMERICAN SUPPLEMENT, with many illustrations of the machinery employed and of the general engineering features of the work.

For the most part the air for the rock drills and for ventilating the tunnels was compressed by water power. At the north end of the tunnel the river Reuss furnished an abundance of water with a fall of 385 feet. This was utilized by means of turbines. On the south side water was scanty, so that it became necessary to work under a fall of nearly 600 feet. The turbines operated 16 air compressors at each end of the tunnel, supplying air enough under a pressure of 8 atmospheres to work from 18 to 20 drills, and to thoroughly ventilate the tunnel. About 600 pounds of dynamite were used daily, and, latterly, as many as 4,000 men were employed.

Many changes were made in the apparatus employed during the progress of the work, and great improvements were introduced. The temperature of the air in the tunnel was found to be always higher than that without. It steadily increased as the excavation proceeded. On the first day it rose from 35° Fahr. to 58°, while the air outside remained at 34°. The average temperature further in was found to be over 70°, while the rock was also much warmer than the surrounding atmosphere. Large bell exhausters were erected at each end of the tunnel for the removal of atmospheric impurities, although artificial ventilation was not needed until the boring was 1,000 meters deep. About 5,000,000 cubic feet of compressed air were forced into the excavation each day from either end, and an exhauster, capable of extracting 16,500 cubic feet per minute, was provided at each.

The contract price for the work was $196.40 a foot, tunnel complete; the work to be done October 1, 1880. For every day beyond that time the contractor was to forfeit $1,000 for the first six months, and $2,000 for each day of the second half year; a year's delay forfeiting the contract and the $1,600,000 deposited by the contractor's friends as security. On the other hand, a premium of $1,000 a day was allowed for each day gained upon the contract time. Accordingly there is due the contractor's successors the snug little premium of $215,000 for the early completion of the work.

Unfortunately the original contractor, M. Favre, did not live to see the accomplishment of his heroic task. While showing the levels to a French engineer, Saturday morning, July 19, he suddenly complained of a cramp, called for a glass of water, and fell down dead from an affection of the heart.

The prospect of losing by the St. Gothard route a large part of the traffic which now passes through the Mt. Cenis tunnel, has driven the French to urge the subsidizing of a project for piercing a still greater tunnel on the Simplon route.

The proposed tunnel strikes the mountain at a lower level than was thought of when the St. Gothard tunnel was projected; and, although its length will be greater, the conditions are so favorable that no doubt is felt in regard to its possible execution. Competent geologists pronounce the rocks of the Simplon less hard than those of St. Gothard, and predict that the work will suffer less from the infiltration of water. There is, besides, abundance of water power at both ends of the tunnel; and from their lower altitude the works will be less liable to interruption by the severity of the winter cold.

The railway extending from Lausanne up the lower part of the Rhone Valley is without curves, while the gradient nowhere exceeds 1 in 100. At its exit on the southern side of the mountain, in the Diviera Valley, the gradient is somewhat stronger—13 in 1000. In fact, when the tunnel is completed, the highest point of the line between Paris and Milan will not be in the Simplon, but between Dijon and Lausanne.

The tunnel will be over 12 miles in length, as compared with the 9 1-3 miles of the St. Gothard, and the 7½ miles of the Mt. Cenis tunnels; and as it is estimated that a daily advance will be made of 9 to 10 meters in the boring, so that the completion of the work is promised in 6 or 7 years after it is fairly begun.

The superior rate of progress in the St. Gothard tunnel over that in the tunnel of Mt. Cenis (9 1-3 miles in 7½ years, against 7½ miles in 13 1-3 years) was due mainly to the great improvements made from time to time in the machinery and explosives employed. The projectors of the Simplon tunnel count on a continuance of such inventive progress.

THE PATENT BILL NOW BEFORE THE SENATE.

We have heretofore pointed out the disingenuousness of the proposed new law, "To regulate practice in suits brought to recover damages for infringement of patents," the injustice it would certainly work to all who have property in patents, its practical confiscation of vested rights in what are assumed to be matters of only small concern to the owners, and the fairly doubtful question of its constitutionality, if tried on a broad issue in the tribunal of last resort. There is little satisfaction, however, to be derived by the owners of patents from the latter consideration, although it ought, indeed, to furnish a leading argument for the de-