

made of the Deep George and the Rothschoberger Stollen in Saxony, the Joseph II. adit at Schemnitz, Hungary, and the Ernest August Stollen, which was later driven under the Deep George. Several tunnels, of which the Taillades tunnel was the most important, were also driven in connection with the Marseilles Aqueduct during this period.

The Deep George Stollen was driven between 1777 and 1799. The total length of the main tunnel is 34,529 ft. Its various branches aggregate 25,319 ft. more, and yet this immense undertaking, driven entirely by hand, was to obtain a drainage depth of only 460 ft. It passed through graywacke for nearly the entire distance.

Work began in the Joseph II. mining adit, at Schemnitz, Hungary, in 1782, but owing to various interruptions the tunnel was not completed until 1878. The portal is at Wornitz, on the left bank of the River Gran, about 10 miles west of Schemnitz. The tunnel is 10.27 miles long, 9 ft. 10 in. high and 5 ft. 3 in. wide, and cost \$4,860,000. It is used entirely for mine drainage, and the annual saving in pumping amounts to more than \$75,000.

The Rothschoberger Stollen was driven to drain the mines of Freiberg, Saxony; it was begun in 1844 and completed April 12, 1877. The tunnel starts in the Triebisch valley, at Rothschoberg, about 12 kilometers above Meissen, on the Elbe. Its length on the line planned to Halsbrücke was 42,662 ft., but as completed to a connection with the Hirmelfahrt mine was, including branches, 95,149 ft. The depth below the Anna Stollen was 308 ft. Hand drilling and black powder were used to the end of 1875, when Burleigh drills were introduced. The work was carried on by the State. The tunnel was 9 ft. square and was driven from 18 headings, yet 33 years were required for its completion, the average rate of progress in each of the headings being only about 15 ft. per month.

The Ernest August tunnel was driven below the Deep George Stollen in 1851-1864. The main tunnel is about 34,218 ft. long, but the entire length of the adit and its branches is 74,452 ft., all driven in rock similar to that in the George Stollen. The tunnel is 11 ft. high and 5½ ft. wide, and is driven on a grade of 35.6 ft. to the mile. Hand drilling and black powder were used, and with 7-hour shifts, the rate of progress was 50 ft. per month; 4-hour shifts increased the rate of progress to 78.7 ft. per month, and by crowding the miners to the limit the progress during the last three weeks was 75 ft., or at the rate of 107 ft. per month.

Some idea of the importance the early German miners attached to drainage may be gathered from the fact that this colossal enterprise gave them an increased drainage depth of only 315 ft.

The Taillados tunnel on the Marseilles Aqueduct was begun in January, 1839, and completed at the close of 1864. It was driven from 14 shafts, and in their construction so much water was encountered that the work of sinking was difficult and at times seemed almost impossible. It was finally necessary to place at one of the shafts a steam engine of 100 horse power in order to remove the water, which amounted to 3,300 gallons per hour. The cost of sinking the shafts was approximately \$40.00 per ft., and the tunnel itself cost approximately \$37 per ft., or, including the cost of the shafts, \$48.50 per ft. The Assassin tunnel on the same project was somewhat less difficult to drive and cost only \$25.50 per ft. for 11,400 ft., whereas the Notre Dame tunnel, which was lined with masonry for its entire length of 11,500 ft., cost \$32.50 per ft.

The first large mining tunnel in the United States was begun as early as 1824. This was the "Hacklebernie" tunnel, near Mauch Chunk, Pa.; it was driven by hand, and black powder was used. When work stopped in 1827 an opening 16 ft. wide by 8 ft. high had penetrated 790 ft. through hard conglomerate. Work was resumed in 1846, and the tunnel was extended to a length of 2,000 ft.

Development of the Use of Rock Drills and High Explosives in Tunneling.

The invention of drilling machines, which occurred almost simultaneously with the discovery of high explosives, gave another great impulse to tunnel driving. The following table gives in Chronological order some of the more important events connected with these two wonderful improvements.

1847—Sobrero discovered nitroglycerin.

1849—J. J. Couch, of Philadelphia, patented on March 29 the first percussion rock drill.

1851—J. W. Fowle, of Philadelphia, patented on March 11 the first direct-action percussion drill.

1854—Schumann invented his percussion drill at Freiberg.

1857—Schumann drills used in Freiberg mines.

1857—Sommeiller invented a rock drill for use at Mount Cenis.

1861—January 1 Sommeiller improved drills commenced work in the Mount Cenis tunnel.

1863—Nobel first applied nitroglycerin as a blasting agent.

1865—Guncotton tried at the Hoosac tunnel by Thos. Doane, chief engineer.

1866.—Nitroglycerin tried with great success at the Hoosac tunnel by T. P. Shaffner.

1866—Burleigh drills tried and proved to be a great success at the Hoosac tunnel.

1867—Nobel invented dynamite.

1868—Dynamite patented in America by Nobel.

The first extensive utilization of these aids was in the construction of the Mount Cenis tunnel in Europe and the Hoosac and Sutro tunnels in this country. The success attained with them soon led to further activity in tunneling, not only for railroads but in connection with mining, drainage and water supply as well—an activity culminating in the immense amount of such work undertaken within the last 10 or 15 years.

The Sutro Tunnel.

The idea of draining the mines of Virginia City by a deep tunnel was first broached in the spring of 1860, when Mr. Adolph Sutro began negotiations with the mines, the State, and finally with the Federal Government for contracts, concessions, etc. Actual work first began at the portal of the tunnel in Carson valley, 3½ miles from Dayton, on October 19, 1869. The work was carried on by hand until September, 1872, when diamond drilling was begun and tried rather unsuccessfully. In 1874 Burleigh drills were introduced, operated by compressed air generated in a compressor made by the Societe John Cockerill, of Seraing, Belgium. The tunnel was completed July 18, 1878, when the Savage vein was cut 20,000 ft. from the portal and 1,922 ft. below its outcrop. The tunnel inside of the timbers was 10 ft. high by 14 ft. wide, divided into two passageways by a central row of posts. The rate of progress varied greatly, ranging from 19 to 417 ft. per month, the average monthly rate from start to finish being 192.3 ft.