

THE HISTORY OF TUNNELLING*

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The art of excavating underground passageways has been known to mankind for many centuries. The ancient Egyptians and Hindus employed it in the creation of many wonderful subterranean temples and sepulchers in hard rock, and similar monuments are found in the works of the Hebrews, Greeks, Etruscans, Romans, Aztecs and Peruvians—in fact, of all ancient civilized peoples.

Egyptian Temples and Tombs.

It is not surprising that the Egyptians, with their wonderful knowledge of quarrying as well as of many other useful arts, should have been versed in methods of underground rock excavation. Remains of their work, some of which dates back to 1500 B.C., may be found in the grottos of Samoun, the tombs near Thebes and Memphis, the catacombs of Alexandria, and the temples of Ipsamboul. A gigantic tomb has been found at Abydos, which was cut in the solid rock during the XIIth dynasty by Senwosri III.; also Rameses II., who is perhaps the best remembered personage of these ancient times, constructed, either because of vanity or the great length of his reign, many rock-cut temples, the grandest of which is probably that of Abu Simbel.

The work was performed with hand tools and the labor necessary to have fashioned monuments of such magnitude and grandeur must have been stupendous. For cutting granite and other hard rock, the workmen used saws of copper, which were either fed with emery powder or were set with teeth of that abrasive. A similar method was employed as early as the fourth dynasty for circular holes, which were drilled by a tube having fixed teeth or fed with emery powder. For removing rock in a quarry or in a tunnel, grooves varying in width from 4 to 20 in. were made on four sides of a block, which was then broken out by the swelling action produced by soaking with water a number of wooden wedges driven into these grooves.

Hindu Caves and Temples.

The excavations in India probably number at least 1,000, the majority of which are of Buddhist origin. They are usually of two types—chapels and monasteries. The chapels consist of a nave with a vaulted roof, separated from the side aisles by columns, and containing a small chapel at the inner circular end. The monasteries consist of a hall surrounded by a number of cells for the residence of monks and ascetics.

Most of the Indian excavations are of much later date than those in Egypt. The earliest, the Sudama or Nigope cave, was constructed probably about 260 B. C., the Lomas Rishi was built about 200 B.C., and those of Nassiek about 129 B. C. These earlier caves imitated very closely contemporaneous timber-roofed temples, and for this reason the columns all slope inward, copying with great fidelity of detail the rafter supports of the wooden temples. In the Karli caves (about 78 B. C.) this feature is absent; the columns of the nave are quite plumb and the perfection of architecture and ornamentation is unsurpassed by any of the later Hindu rock temples. The galleries and rooms of the caves of Ellora contain a total of nearly five miles of subterranean work. Although the builders may possibly have known of gunpowder, it was not used in the construction of these tunnels, which, like

all the preceding works, were accomplished laboriously with hand tools and probably by slave labor. The caves of Salsette belong to the sixth century A. D., whereas those at Elephanta were constructed about 800, and the Gwalior temples were excavated still later, during the fifteenth century.

Grecian Tunnels and Mines.

Modern archaeological investigation indicates that tunneling was possibly known to the Minyae, an ancient Grecian people dating back beyond 2000 B. C., whose cycle of myths includes, among others, that of the Argonautic expedition. A series of shafts, 16 in all, are to be seen near Lake Kopais, in Boetia, which are supposed to have been constructed by these peoples for the ventilation of an ancient drainage tunnel. The shafts are 200 to 1,000 ft. apart, 6 to 9 ft. wide, and have a maximum depth of 100 ft. The tunnel was probably the enlargement of a natural watercourse, such as are commonly found in similar calcareous rocks. Krates, of Chalkis, a mining engineer who lived in the time of Alexander the Great, is credited historically with an attempt to drain this lake by utilizing and enlarging natural watercourses.

Although the exact date of the introduction of mining into Attica, probably from the Orient, is unknown, it seems to have been subsequent to the time of Solon (about 600 B. C.). By 489 it is certain that the silver mines of Laurium were yielding a highly satisfactory return, and at the instigation of Themistocles the net profits from them were applied by the Athenians to the construction of a fleet, so that these mines no doubt contributed largely to the prosperity and power of Athens. The workings, approximately 2,000 in all, consisted of shafts and galleries in which the rocks were hewn out with hand tools and brought to the surface on the backs of slaves. Air was supplied to the large underground stopes or chambers by ventilating shafts about 6 ft. square and 65 to 400 ft. deep.

Gold was mined in Macedonia and Thrace at least as early as the fifth century B. C., and Herodotus mentions a tunnel in the island of Samos, built in the sixth century, which was 8 by 8 ft. in cross section and nearly a mile long.

Aztec Mines.

The Aztecs were well acquainted with mining, and they obtained copper from the mountains of Zactolan; the mines of Tasco furnished silver, lead and tin; and the extensive galleries and other traces of their labor were of great assistance to the early Spanish miners. With no knowledge of iron, although iron ore was very abundant, their best tools were made of an excellent substitute in the form of an alloy of copper and tin. With tools of this bronze they could not only carve the hardest metals, but with the aid of powdered silica they could cut the hardest minerals, such as basalt-porphry, and even amethyst and emerald.

Peruvian Mines.

Although the mines of the ancient Peruvians were little more than caverns excavated in the steep sides of the mountains, nevertheless they knew of the art of tunneling, as is shown by the tunnels of their aqueducts and by the extensive tunnel that they built to drain Lake Coxamarca. They, too, had no knowledge of iron, and their tools were made of an alloy of copper

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