1 Introduction

What sent humans underground? Was it for protection, to look for minerals, or for shelter? There is evidence of tunneling long before recorded history. Perhaps, after the surface outcropping of flint was depleted, humans went underground and became the first miners. In this book, the terms mining and tunneling will be used interchangeably; however one could argue that tunneling came first. Humans mined on the surface until they ran out of surface mineral and then had to tunnel to reach the minerals they sought. Simply put, mining is defined as digging underground to extract a substance of value, whether it be an ore such as gold or a material with an industrial use such as mica, whereas tunneling is digging under the surface of the earth for the sake of making the hole itself. The hole may be for transportation, water and wastewater, defense, storage, or any other need to go underground. Historically, the two principal reasons for tunneling were for water and warfare. Many engineering disciplines have existed for hundreds of years. Military engineering as a discipline resulted from the need to fortify military structures and for breaching fortifications. With military engineering, civil engineering evolved at about the same time. Later aeronautical engineering, nuclear engineering, and electrical engineering were developed. Compared to early engineering, these disciplines are relatively young. Documentation indicates that geotechnical engineering, the most important discipline used in tunneling, has its origins in the eighteenth century. Metallurgy can be traced back to when early humans first started mining and processing metals, for example, copper and iron. Tunnel/mining engineering is probably the oldest engineering discipline. When humans used an antler and dug a hole, they had to make sure that the hole would remain open and not collapse. Some soils may have stood without support, but some did not. How they solved this problem is unknown. Possibly after they used logs to build shelters, they also used logs and branches for support. What about before this? Perhaps they learned to dig their tunnels below trees so that the roots would hold the soil. Maybe archeologists have some answers.

Since more tunnels were driven before tunnel engineering existed, what does this discipline bring to the endeavor? Tunnel engineering can be divided into two areas: tunnel design and tunnel construction. Although there is some overlap between these two areas, both require the same information, but for different reasons. The tunnel designer is interested in the geotechnical properties of the ground. This information, which includes ground strength parameters, water, and so on, is used to help determine tunnel alignment, depth, type of lining necessary, and other details to safely provide the end use. The tunnel
designer must have a sense of what is practical. Because tunnels are expensive, the designer must come up with the most cost-effective design to achieve the goals for the tunnel. The tunnel designer must have enough knowledge of tunneling techniques to make sure the design is “constructible.” Often the tunnel construction engineer is involved with the designer to provide construction insights. The tunnel construction engineer may then assist construction by providing design insights to the tunneler.

Historically, tunneling has been filled with hazards. Miners have been killed or maimed by poisonous gases, cave-ins, falls, and fire; some have been crushed by equipment; and some have been worked to death, for example, slaves. Although many improvements have been made in the last 100 years, some of these hazards still exist. In the middle of the last century, one could assume that there would be one death per mile of tunnel. Fortunately, that statistic no longer exists. The most important contribution that the tunnel construction engineer can make to tunneling is safety. There is no need to discuss the moral and economic reasons for this; they are well known.

Like the designer, the tunnel constructor is interested in the geotechnical attributes of the tunneling medium. Like the designer, he or she needs to determine the ground support required, the best mining method, in the case of rock the anticipated bit life, and so on. The constructor also needs to know about the water, not so much from the final lining perspective, but how to handle the water during mining.

Tunnel engineering is still very much an art. There are models that will provide a great deal of insight as to the in situ geotechnical parameters; however, the decision in the field could very well be made by someone who does not know the name of the rock being tunneled through but knows what will hold it up. Tunneling is referred to as a “gray beard” business. That is, experience is a critical factor in tunnel engineering. In a typical civil engineering design office, there will be a few older engineers, but the majority of engineers will be younger engineers who are there to apply what they learned in school under the guidance of older engineers. Because it takes years to learn the art of tunneling, a typical tunnel design office generally has a larger percentage of older engineers. This is illustrated if we look at steel and concrete versus rock and soil. Steel and concrete have known strength parameters and it is known how they will act in various circumstances. This is not the case with rock and soil. All that one can truly depend on learning from a boring is what is in the boring. The geologic material could change inches away. Therefore, tunnel engineers have had to have seen similar material and have an opinion of how it acts under various conditions.

The tunnel engineer does not get to choose the tunneling conditions. Unlike surface construction where the conditions are generally visible, the tunneler is going into areas with conditions he or she can only assume. Later in the text, the engineering properties of rock and some of the exploration techniques used to try to determine those properties are discussed. Despite all of the exploration and engineering analysis, the most important piece of information the engineer needs to know about rock is the boring. The rock type and characteristics can
change next to the borehole. There may be an outcropping that indicates the strike and dip of discontinuities, but in a deep tunnel that may provide little information; geophysical methods of exploration may be used, but these methods are limited. When all exploration tools are available, the tunnel engineer can be quite good at predicting the conditions. Despite this gloomy description of the knowledge that tunnel engineers have before tunneling commences, based on the exploration and analysis, they are good at predicting conditions. However, one still has to exercise caution and be prepared for surprises.

Some believe that these problems are what make tunneling interesting. Attracted to the unknown, the miner is prepared to enter the bowels of the earth and handle any problem, whether it be a change in the ground conditions or unexpected inflow of water. They may have to modify the mining method or ground support or both or grout to seal or slow the inflow of water, but they keep driving forward. Miners do not like to not advance the face. Although the work is hard and dirty, when a tunnel breaks through in the right place, the tunneler remembers it was done blind. As when early explorers had maps but the maps were incomplete, the miner has geotechnical reports that cannot tell them everything that will be encountered. Tunnellers, just as they did a thousand years ago, enter a world of unknown conditions and risks and succeed.

The oldest and largest known qanat is in the Iranian city of Gonabad and after 2700 years still provides drinking and agricultural water to nearly 40,000 people. The main well is more than 360 m (1180 ft) at its deepest and has a length of 45 km (28 miles). It took a special individual to build this water supply.

The military application, like the qanats, can also be traced back thousands of years. Early combatants would tunnel under the walls of the city or under the enemy’s lines to plant explosives to breach the walls or to smuggle in soldiers to take the enemy from the rear. In early January of 1917, British General Sir Herbert Plumer issued orders for 20 mines to be placed under German lines at Messines. For the next five months more than 8000 m (5 miles) of tunnels were dug under enemy positions and 600 tons of explosives placed in position by miners hired by the military. Simultaneous explosion of the planted explosives occurred on June 7. The blast, which was so loud that it was heard in London, killed an estimated 10,000.

What makes a tunneler willing to violate the earth and venture into the unknown subsurface? To tunnelers the sounds of water flowing or air leaking from a pipe when equipment is not running, the texture of blasted rock, the smell of stale water and oils and other lubricants, the darkened environment where they learn to see with less light, and the taste of salt in their own sweat are what make them feel at home. In one of the most dangerous work environments in modern industry, the tunneler feels safe.

Why do tunnelers do this? Perhaps they are the third generation in their family to make this journey. And a journey it is. Perhaps they are attracted to going into an unknown environment. If one can forgive the use of a contemporary phrase, they do it because they go where no man has gone before.