or both. Theoretically, there is but one tunnel section that is most economical, with reference to a given condition of loading, but, in actual practice, it would be impractical to change the cross-section very often. Furthermore, certain clearance lines for the rolling stock and for other purposes have to be strictly observed. It is also desirable that the forms and tunnel centres be made as uniform as possible. For the above reasons, it is usually the practice to design a few types of lining sections, the strength of which is determined *a priori*, adapting these where found necessary, according to the conditions of loading, or pressure acting on the lining.

In Fig. 3 an attempt has been made to illustrate several typical tunnel cross-sections adaptable to resist best ground pressure, under various conditions of loading. Here the bore is assumed to penetrate materials of variable cohesion, at a variable depth below the surface, and for the sake of illustration, zones of variable formation have been assumed. Section A-A, Fig. 3, is that usually adopted for stream or river under-crossings, when the material penetrated consists chiefly of silt, mud, drift, sand, quicksand, and, in general, materials well saturated, and exerting pressure throughout the periphery of the lining. The tunnel section best suitable to resist the internal stresses thereby borne is circular. This section has been adopted in connection with the several tunnels driven under the Hudson and East Rivers, the Thames River, as well as other tunnels in America and abroad.

Zone 2, Fig. 3, consists of alluvial or glacial deposits, such as sand and gravel, boulders, clay, etc., materials more or less stable and capable of being tunnelled without the assistance of compressed air or of a shield, but exerting, nevertheless, lateral pressure on the lining on account of the small angle of repose of such materials. For the purpose of resisting this pressure, the intensity of which may be high, the side walls of the tunnel are arched, and an invert is required, most usually to counterbalance the reaction of the side walls, at floor elevation, and incidentally to take care of upward pressure, should such pressure develop. As the intensity of ground pressure is a function of the width of the bore and of the cohesion of the material penetrated, it becomes evident that the bore should be given as small a width as practicable; therefore an elliptical section here answers better the purpose than would a circular section.

Zone 3 consists of weathered materials, not water-bearing, and exerting chiefly vertical pressure on the tunnel roof, and little lateral pressure, if any. Owing to the comparatively low compressive strength of the material penetrated, the base of the side walls is given a broad dimension. as shown in section C-C, so as to provide adequate abutments for the tunnel roof or arch, thus reducing the intensity of passive pressure on the material adjacent to the tunnel side walls, at springing line elevation. Should now the intensity of pressure on the roof of the bore become such as to cause possible settlement or sinking of the side walls below floor elevation, then a masonry invert is provided, as shown in D-D.

Zone 4 consists of hard and solid stratified rock, capable to stand without timbering upon being tunnelled, except that occasional falls of rock, loosened through the process of tunnelling, are to be anticipated. In such a case, a lining having a minimum practical thickness with vertical or slightly battered side walls answers the purpose.

Zones 5 and 6 consist of hard and solid materials. The bore is deeply overlaid, and in zone 5 vertical pressure develops in the roof, thus necessitating a heavy lining.

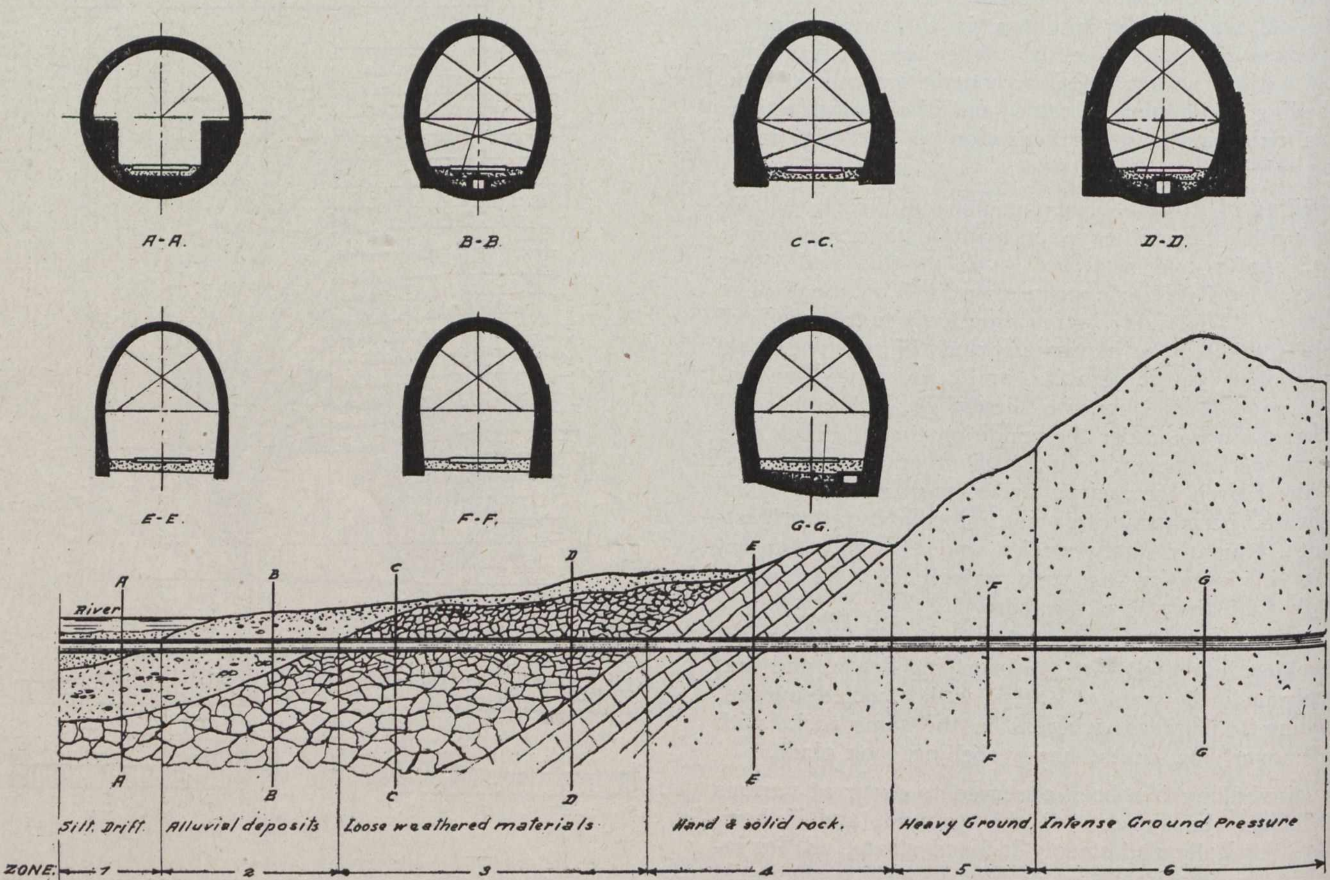

Fig. 3.