1.2 Physical properties of earth materials

Before introducing the methods of applied geophysics, a brief review of the properties of earth materials that can be directly or indirectly mapped will illustrate why these methods are important for a wide range of subsurface studies. The range of values for the physical properties that can be measured with the methods of applied geophysics are shown schematically in Figure 1.2.1. For some the range is enormous. Electrical conductivity for earth materials may be as low as 10^-5 for igneous rocks and as high as 10^4 for graphite. Density on the other hand has a relatively narrow range from 1 to less than 10. These ranges are important in determining the sensitivity of a measured property to the underlying rock property that is desired. For example a very small change in fluid saturation can lead to a big change in measured electrical conductivity but a small change in mineral composition or porosity leads to a relatively minor change in bulk density. The relationship between the measured physical properties and the desired rock or soil properties is a central issue for applied geophysics. Ultimately the usefulness of an interpretation of a field survey depends on the accuracy of this relationship. For purposes of a qualitative introduction to this aspect of applied geophysics Table 1.2.1 shows the degree to which the measured property is related to the property of interest. The rock properties or targets are located in the left hand column of Table 1.2.1 and the physical properties measurable with the geophysical methods are located across the top. The shaded matrix entries indicate the degree to which the measured property is dependent on the properties of interest. The scale is subjective and is only to be used qualitatively in the following discussion.

It is important to note, by scanning down the columns, the extent to which the measured property depends on many of the derived properties. Velocity
depends on water content, porosity, clay content and the elastic and mechanical properties. Electrical conductivity depends on porosity, saturation, pore fluid conductivity, and clay content. An equally important point is that the desired properties usually depend on several of the measured properties. So it is that water content is strongly related to dielectric constant, conductivity and velocity, while metallic objects may be detected by their magnetic susceptibility conductivity and possibly density but not much else. These horizontal associations in the matrix chart point out, early in this course, the importance of using multiple methods to reduce the ambiguity in determining the properties of interest. In the microscopic or constitutive sense, each of the measured properties depends on the desired properties in a different way so that the joint measurements usually narrow the range of desired properties that are compatible with the data. For example, velocity is very sensitive to saturation (air-water) but hardly at all to fluid composition. Conductivity, on the other hand, is very sensitive to both saturation and pore fluid conductivity. If saturation is determined from velocity, the fluid type can be determined uniquely from conductivity.