2.3 Density of minerals, soils and rocks

The densities of the commonest rock forming minerals are remarkably close together. The bulk densities are often more controlled by the porosity and the degree of cementation than by the mineral composition. The following brief table lists the densities for a few common minerals.

Mineral	Density
Quartz	2.65
Felspar	2.6
Biotite mica	2.9
Calcite	2.6 – 2.7

Rocks made up of these minerals tend to be less dense due to porosity but with increasing depth of burial compaction reduces the porosity and most of the rocks comprising the crust of the Earth have a density between 2.6 and 2.7.

The effect of density on porosity follows a mixing law. The porosity, ϕ, is the fractional pore volume of a rock. The total mass of a volume of rock V_T is made up of the mass of the pore fluid, of density ρ_f, plus the mass of the matrix minerals of density ρ_{ma} The density measured is the bulk density ρ_b. The total mass then becomes:

$$\text{Total mass} = V_T \rho_b = \phi V_T \rho_f + (1-\phi) V_T \rho_{ma} \qquad (2.3.1)$$

So we have a formula for the bulk density in terms of the porosity, pore fluid density and the matrix density:

$$\rho_b = \phi \rho_f + (1-\phi) \rho_{ma} \qquad \text{The Mixing Law for density} \qquad (2.3.2)$$

From the mixing law we can then find the porosity via:

$$\Phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \tag{2.3.3}$$

In some geological situations where there is rock exposure, or where a hole has been drilled, the rock or soil type is known so matrix densities can be assigned. Fluid densities are also known so the measurement of bulk density yields porosity. In borehole gravity surveys core samples or chip samples identify the matrix minerals very well so with accurate density determination the porosity can also be determined very accurately.

Some basic igneous rocks which not only have very low porosity but contain more iron rich mafic minerals than their upper crustal counterparts have densities from 2.8 to 3.0 and some exotic rocks of deep seated origin have densities as high as 3.4 (eclogite).

Soils on the other hand can have relatively low densities due primarily to the higher porosity but also because common clays have densities around 1.6 to 2.6. Some representative values for soils , sands, and gravels are:

Soil	**Density**
Gravel	2.0
Sand	2.0
Unsaturated overburden	1.9

A useful summary for the range of densities observed for small sample bulk densities of common rock types is shown below in Table 2.3.1.

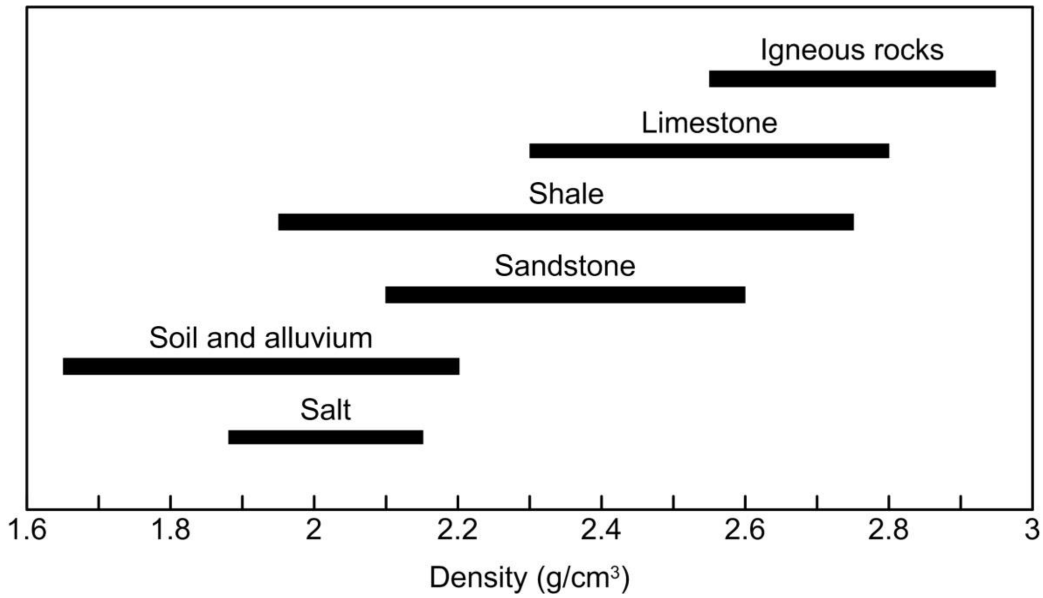

Table 2.3.1

Ore minerals, oxides and sulfides of various metals are relatively dense:

Mineral	**Density**
Chromite	4.36
Magnetite	5.1
Chalcopyrite	4.2
Pyrite	5.0
Galena	7.5

Salt is of particular interest in sedimentary rocks because it is low density, 2.2, but has a fairly high bulk modulus giving it a relatively high seismic velocity.

With the exception of salt and ore deposits the contrasts encountered in gravity studies of the crust rarely exceed 0.25 gm cm^{-3}. For shallow studies the contrasts are higher and gravity methods are useful for mapping overburden thickness. The large overlap in the densities of most rock types seen in Table 2.3.1

shows that it is impossible to extract the rock type from an inferred density obtained from a gravity survey.