4 Metamorphic terrains II

Regional metamorphism

Most metamorphic rocks occur in fold mountain chains or in continental shields, which may be the eroded root zones of ancient mountain chains. Such metamorphic rocks therefore cover large areas of the continental crust (Fig. 4.1). They are termed regional metamorphic rocks and they include such types as schists and gneisses. Regional metamorphic rocks arise by the combined action of heat, burial pressure, differential stress, strain and fluids on pre-existing rocks (see p. 3 & pp. 20–25 for an explanation of these terms). The resulting rocks are always deformed and they exhibit such characteristics as folds and cleavages (Fig. 4.2). Large amounts of granite are often associated with regional metamorphic rocks, for reasons that will be explained later (p. 88).

As in contact metamorphic rocks, certain index minerals grow in response to increasing pressure and temperature. These index minerals are used in the field to define regional zones of increasing metamorphic grade.

Regional metamorphism covers a wide range of pressure and temperature conditions, roughly from 200 °C to 750 °C and 2 kbar to 10 kbar (5–35 km depth, approximately). It is necessary to divide this wide range up into smaller, more manageable segments that reflect geological environments. The means used to subdivide the pressure–temperature space of regional metamorphism into different fields is the mineral assemblage of metamorphic rocks. The results of laboratory experiments on the growth and stability of metamorphic minerals at various pressures and temperatures are incorporated with microscope studies of the mineral assemblages, textures and fabrics of metamorphic rocks to provide estimates of the conditions of metamorphism. Rock types that respond most readily to variations in pressure and temperature are fine-grained pelitic sediments (shales and mudstones) and basic igneous rocks with the composition of basaltic lavas. These are the types that are used to define regional metamorphic facies (p. 40) in orogenic belts.

Regional metamorphism of pelitic rocks. The study of metamorphic rocks was begun in a serious way about a century ago by geologists such as George Barrow who worked in the Dalradian schists of the
south-west Scottish Highlands (Fig. 3.6). There, the metamorphosed pelitic and basic rocks contain a large number of silicate minerals, and Barrow made the observation that some of these minerals could be used as indicators of metamorphic grade. Table 4.1 lists the common silicates found in metamorphosed pelitic and basic rocks. Minerals used as metamorphic indicators are marked with an asterisk in the table. The minerals which are likely to be unfamiliar to you are andalusite, kyanite, sillimanite, cordierite and staurolite (see Table 1.1). Note especially that the minerals in Table 4.1 cannot all be found together in the same rock. Andalusite, kyanite and sillimanite are described as the aluminosilicate polymorphs (p. 11): although they have the same composition, the three varieties have quite different crystal structures and physical properties (see Fig. 4.3 & Table 1.1). They are sensitive to pressure and temperature changes and usually only one of the polymorphs is present in a particular metamorphosed pelitic rock of the appropriate composition.

Figure 4.1 Shield areas of Europe.

Figure 4.2 Photographs of deformed rocks. (a) Folds in banded gneiss, Karelia, USSR; (b) steep schist belt cutting through banded granulite, Lewisian Gneiss Complex; (c) schist in shear belt cutting through coarse hornblende–feldspar gneiss, Lewisian Gneiss Complex.