3 The non-silicates

3.1 Introduction

Minerals which are not silicates have been grouped together in this chapter for the description of their properties. However, unlike the silicates, the crystal structures and chemical variation of members of the group are not easily related to mineralogical properties and the mode of occurrence. Even subdivision of the group into transparent and opaque minerals is impractical, since closely related minerals, and even compositional varieties of the same mineral, may vary in opacity. For example, sphalerite is transparent when it is pure zinc sulphide, but it becomes progressively more opaque with increasing iron substitution of zinc (see Plate 4a).

The non-silicates can usually be regarded as accessory minerals in most rocks, yet they are major components in some rock types, e.g. halides in evaporites, sulphides in massive sulphide deposits and carbonates in limestones.

Minerals of the following non-silicate groups appear in this chapter in alphabetical order: arsenides (As\(^{2-}\)), carbonates (CO\(_3^{2-}\)), halides (Cl\(^{-}\), F\(^{-}\)), hydroxides (OH\(^{-}\)), native elements, oxides (O\(^{2-}\)), phosphates (PO\(_4^{3-}\)), sulphates (SO\(_4^{2-}\)), sulphides (S\(^{2-}\), S\(_2^{2-}\)) and tungstates (WO\(_4^{2-}\)). Within each group, the minerals are described in alphabetical order. The relationship of the optical and physical properties to the chemical composition and structure is outlined only for the four major groups: carbonates, halides, oxides and sulphides.

In this chapter, where appropriate, thin-section information is as described in Section 1.4 and presented for the silicates in Chapter 2. The polished-section information, for observations using reflected light, is as described in Section 1.7.

3.2 Arsenides

Niccolite NiAs

The name recommended by the International Mineralogical Association is nickeline. Niccolite may contain some Fe or Co.

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Niccolite is hexagonal, $a:c = 1:1.3972$. Crystals are rare. It is usually massive, reniform with columnar structure. Repeated twinning occurs on $\{10\overline{1}\}$. There is no cleavage. $D = 7.8$. $H = 4\frac{1}{2}$.

Polished section  Niccolite is pinkish or orange white with a pronounced pleochroism, with $R_o = 52\%$ (lighter, orange or yellowish) and $R_e = 48\%$ (darker, pinkish). The reflectance is similar to pyrite. Anisotropy is very strong, the tints being bright bluish and greenish greys.

Niccolite usually occurs in xenomorphic or concentric, botryoidal masses with other Co + Ni + As + S minerals. Grains are often cataclased. Growth zonation is common, and botryoidal masses often contain radiating intergrown irregular lamellae (Fig. 3.1). VHN = 328–455.

Occurrence  Niccolite occurs in Ni + Co + Ag + As + U deposits, which are probably low-temperature hydrothermal veins and replacements. Such deposits are often associated with basic igneous rocks and organic-rich sedimentary rocks.

Distinguishing features  Compared with niccolite, marcasite is whiter, and arsenopyrite is whiter and has a weaker anisotropy.

Note  Niccolite alters to green annabergite.

### 3.3 Carbonates

The carbonates, of which the best known example is calcite $\text{CaCO}_3$, contain a discrete $(\text{CO}_3)^{2-}$ radical that may be considered as a single anion in the structure, but is in fact a trigonal planar complex. This complex, with carbon in the centre of an equilateral triangle formed by three oxygens, is shown in the carbonate structure in Figure 3.2.