16 Mining-induced surface subsidence

16.1 Types and effects of mining-induced subsidence

In the present context, subsidence is the lowering of the ground surface following underground extraction of an orebody. Subsidence is produced, to a greater or a lesser degree, by almost all types of underground mining. Surface displacement may result from the redistribution of stresses associated with excavation or from mining-related activities such as de-watering.

Subsidence can be regarded as being of two types – continuous and discontinuous. Continuous or trough subsidence involves the formation of a smooth surface subsidence profile that is free of step changes (Figure 16.1). The resulting displacements of surface points may be of only elastic orders of magnitude when compared with the dimensions of the subsiding area or the mining depth. This type of subsidence is usually associated with the extraction of thin, horizontal or flat-dipping orebodies overlain by weak, non-brittle sedimentary strata. It results from the longwall mining of coal, but has also been associated with the extraction of a wide variety of other minerals such as sulphur and the evaporites deposited in sedimentary environments. Methods of predicting subsidence profiles in these cases are discussed in section 16.5.

Discontinuous subsidence is characterised by large surface displacements over limited surface areas and the formation of steps or discontinuities in the surface profile. It may be associated with a number of mining methods, may involve a range of mechanisms, may develop suddenly or progressively, and may occur on a range of scales. Figure 16.2 illustrates some of the forms of discontinuous subsidence.

Crown holes (Figure 16.2a) arise from the collapse of the roofs of generally abandoned, shallow open workings. Much of the surface damage in the anthracite mining region of northern Pennsylvania, USA, is due to this cause. Crown holes are also associated with old coal, ironstone and flint workings in England (Piggott and Eynon, 1978). Crown holes may be regarded as a special case of chimney caving which is discussed in detail in section 16.2.

Pillar collapse in old, shallow workings may lead to similar surface expressions of discontinuous subsidence as does crown hole formation. Such collapses may occur as a result of a deterioration in pillar strength with time or the imposition of additional load on the pillar by surface construction. Large-scale pillar collapse in a working mine can produce discontinuous subsidence over a larger area with more serious effects. A most catastrophic failure of this type occurred at the Coalbrook North Colliery, South Africa, on 21 January 1960, when a room-and-pillar mining area covering approximately 3 km² suddenly collapsed with the loss of 437 lives (Bryan et al., 1964).

Chimney caving, piping or funnelling (Figure 16.2b) involves the progressive migration of an unsupported mining cavity through the overlying material to the surface. The surface subsidence area may be of a similar plan shape and area to
the original excavation. Chimney caves may form in weak overburden materials as on the Zambian copper belt, in previously caved material or in regularly jointed rock which progressively unravels. Chimney caves have been known to propagate upwards to surface through several hundreds of metres.

If chimney formation is sudden rather than progressive, the phenomenon is sometimes known as plug subsidence (Figure 16.2c). Generally, plug subsidence is controlled by some structural feature such as a dyke or a fault which provides a plane of weakness whose shear strength is overcome at some critical stage of mining. Underground air blasts are generally produced by this form of subsidence.

Chimney caving was the cause of the Mufulira Mine disaster in which 89 men were killed when 450,000 m³ of mud (tailings) flooded part of the mine on 25 September 1970. A chimney cave propagated upwards by about 500 m to connect the sublevel caving mining area with the overlying tailings pond. The most disastrous consequence of this was the loss of so many lives, but a further important consequence was the sterilisation of a major part of the mine which was subsequently isolated between concrete bulkheads. The Final Report of the Commission of Inquiry (1971) makes salutory reading for aspiring mining engineers.

Chimney caves are sometimes known as sinkholes. However, this term is also used to describe the subsidence features associated with pre-existing solution cavities in dolomites and limestones (Figure 16.2d). The characteristics of these

Figure 16.2 Types of discontinuous subsidence: (a) crown hole; (b) chimney caving; (c) plug subsidence; (d) solution cavities; (e) block caving; (f) progressive hangingwall caving.