15 Aquifer structures: fracture zones and caves

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15.1 Hydraulic importance of fracture zones and caves

Fracture zones and caves (karst caves, volcanic caves) can play an important role for groundwater supply and generally in hydrogeological and environmental geological practice. In most cases fracture zones are considered hydraulic conductors, but they may sometimes also act as hydraulic barriers preventing flow across them (Committee on Fracture Characterization and Fluid Flow et al. 1996). The porosity of the fractures is called secondary porosity. Rock material can contain smaller fissures, e.g. by contraction while cooling, or larger fractures by tectonic movements along fault zones (Fig. 15.1). Fissured rocks have similar petrophysical properties as primary-porous material, so in principle the same geophysical techniques as for the exploration of water reservoirs in primary-porosity material can be applied (Chap. 14).

[Image of fissures and fractures in rocks]

Fig. 15.1. Fissures (I) and fractures (II) in rocks (Schneider 1988)

In addition, fracture zones are a special target for geophysical and hydrogeological exploration, because in general, hydraulic and petrophysical properties of fracture zone and host material are strongly different. Although extending over large distances, the width of fracture zones is mostly narrow. Moreover, the dip angle of fracture zones must be taken into account for the siting of wells (Fig. 15.2).
Frequently, the strike direction of fracture zones is known from tectonic considerations. Fracture zones can often be detected as lineation structures in satellite imagery or on air photos. However, for a successful groundwater exploration this remote mapping must be backed by airborne or ground geophysical surveys. Even a localisation error of the fracture zone as small as 10 m can result in a dry borehole (van Lissa et al. 1992).

Karst and volcanic caves are a further important class of aquifers. Formed by dissolution of carbonate rocks (limestone, dolomite), karst caves and channels are found mainly along tectonic fractures or horizontal layer boundaries (Fig. 15.3). Enhanced dissolution of limestone occurs in coastal areas in the transition zone between seawater and freshwater leading to widespread karst caves, e.g., in the Yucatan peninsula (Mexico) and on the Bahamas (Mylroie and Carew 1990). Apart from lava tubes, large voids in volcanic rocks are related with pillow basalt formation, with highly vesicular, broken zones at the top and bottom of lava flows, and with volcanic caldera collapse.