GYPSISOLS (GY)

Gypsisols are soils with substantial secondary accumulation of gypsum (CaSO$_4$.2H$_2$O). They are found in the driest parts of the arid climate zone, which explains why leading soil classification systems labeled them ‘Desert soils’ (USSR), Aridisols (USDA Soil Taxonomy), Yermosols or Xerosols (FAO, 1974).

Definition of Gypsisols

Soils
1 having a gypsic or petrogypsic horizon within 100 cm from the soil surface; and
2 having no diagnostic horizons other than an ochric or cambic horizon, an argic horizon permeated with gypsum or calcium carbonate, a vertic horizon or a calcic or petrocalcic horizon underlying the gypsic or petrogypsic horizon.

Common soil units:
Summary description of Gypsisols

*Connotation:* soils with substantial secondary accumulation of calcium sulfate; from L. *gypsum*, gypsum.

*Parent material:* mostly unconsolidated alluvial, colluvial or eolian deposits of base-rich weathering material.

*Environment:* predominantly level to hilly land and depression areas (e.g. former inland lakes) in regions with an arid climate. The natural vegetation is sparse and dominated by xerophytic shrubs and trees and/or ephemeral grasses.

*Profile development:* AB(t)C-profiles with a yellowish brown ochric surface horizon over a pale brown or whitish cambic or (relic ?) argic subsurface horizon. Accumulation of calcium sulfate, with or without carbonates, is concentrated in and below the B-horizon.

*Use:* deep Gypsisols located close to water resources can be planted to a wide range of crops. Yields are severely depressed where a petrogypsic horizon occurs at shallow depth. Nutrient imbalances, stoniness, and uneven subsidence of the land surface upon dissolution of gypsum in percolating (irrigation) water are further limitations. Irrigation canals must be lined to prevent the canal walls from caving in. Large areas with Gypsisols are in use for low volume grazing.
Regional distribution of Gypsisols

Gypsisols are exclusive to arid regions; their worldwide extent is probably of the order of 100 million hectares. Major occurrences are in and around Mesopotamia, in desert areas in the Middle East and adjacent central Asian republics, in the Lybian and Namib deserts, in southeast and central Australia and in the southwestern USA. Figure 1 presents an overview of major Gypsisol areas.

Figure 1. Gypsisols worldwide.
Associations with other Reference Soil Groups

Gypsisols are found in the same climatic zone as Calcisols. Note that the presence of a gypsic or petrogypsic horizon is diagnostic for Gypsisols but that accumulation of gypsum occurs also in other Reference Soils. Vertisols, Solonchaks, Gleysols or Kastanozems with clear signs of gypsum accumulation intergrade with the Gypsisol Reference Group but do not key out as Gypsisols because of diagnostic properties other than a gypsic or petrogypsic horizon.
Genesis of Gypsisols

Most Gypsisols formed when gypsum, dissolved from gypsiferous parent materials, moved through the soil with the soil moisture and precipitated in an accumulation layer. Where soil moisture moves predominantly upward (i.e. where a net evaporation surplus exists for an extended period each year), a gypsic or petrogypsic horizon occurs at shallower depth than a layer with lime accumulation (if present). Gypsum is leached from the surface soil in relatively wet winter seasons. In arid regions with hot, dry summers, gypsum (CaSO$_4$.2H$_2$O) dehydrates to loose, powdery hemihydrate (CaSO$_4$.0.5H$_2$O), which reverts to gypsum during the moist winter. The so-formed (highly irregular) gypsum crystals may cluster together to compact layers or surface crusts that can become tens of centimeters thick. Gypsum precipitates in the soil body as fine, white, powdery crystals in former root channels ('gypsum pseudomycelium') or in pockets, or as coarse crystalline ‘gypsum sand’, or in strongly cemented petrogypsic horizons. In places it forms pendants below pebbles and stones or rosettes ('desert roses').

The accumulated gypsum is rarely formed in situ, but there are exceptions. ‘Intrazonal’ Gypsisols (formed under a dominant influence of local material or relief) have been reported from sites where sulfate-rich groundwater occurred at shallow depth. Another example was reported from areas with pyritic sediments in southwest Siberia where sulfate ions, formed when sulfides oxidized upon forced drainage of the land, precipitated as gypsum at depths of 20 to 150 cm below the surface of the soil. In the Republic of Georgia, gypsum was seen to form where saline, Na$_2$SO$_4$-containing, seepage water came in contact with Dolomite weathering. By and large, however, the gypsum in Gypsisols originates from Triassic, Jurassic and Cretaceous evaporites or from (predominantly) Miocene gypsum deposits.
Characteristics of Gypsisols

Morphological characteristics
The typical Gypsisol has 20 to 40 cm of yellowish brown, loamy or clayey surface soil over a pale brown subsurface soil with distinct white gypsum pockets and/or pseudo-mycelium. The surface layer consists of strongly de-gypsified weathering residues and has a low organic matter content and a weak, subangular blocky structure. Gypsum accumulation is most pronounced in the subsurface layer or slightly deeper and can be anything from a gypsic horizon with a soft, powdery and highly porous mixture of gypsum, lime and clay, to a hard and massive petrogypsic horizon of almost pure, coarse gypsum crystals.

Hydrological characteristics
Gypsisols feature a wide range of hydraulic properties. Saturated hydraulic conductivity values vary from 5 to >500 cm/d. The infiltration of surface water is almost nil in severely encrusted soils. By contrast very high percolation losses occur in soils in which dissolution of gypsum has widened fissures, holes and cracks to interconnected subterranean cavities. Infilling of the cavities with surface soil material makes it necessary to level the land surface each year. This makes the valuable topsoil ever shallower. See Figure 2.

Figure 2. Cavity formation, uneven subsidence, and stripping of the surface soil upon prolonged irrigation of shallow Gypsisols. Source: Van Alphen & Romero, 1971. Click to play the movie.
Physical characteristics

Most de-gypsified surface layers contain more than 40 percent clay and have an 'available' water holding capacity of 25 to 40 volume percent. Surface soils with more than 15 percent gypsum have seldom more than 15 percent clay and their retention of 'available' soil moisture does not exceed 25 volume percent. Loamy surface soil slakes easily and subsequently forms a finely platy crust at the surface that hinders the infiltration of rainwater and promotes sheet wash and gully erosion.

Chemical characteristics

Small quantities of gypsum are not harmful to plants but gypsum contents of more than 25 percent, as common in gypsiferous subsoil, upset the nutrient balance and lower the availability of essential plant nutrients such as phosphorus, potassium and magnesium.

The total element contents of Gypsisol surface horizons are typically less than 2500 mg N/kg, 1000 mg P$_2$O$_5$/kg (of which less than 60 mg/kg is considered 'available'), and 2000 mg K$_2$O/kg: application of fertilizers is required for good yields. The cation exchange capacity (CEC) is conditioned by the clay content of the soil material; it is typically around 20 cmol(+)/-kg in the surface soil and around 10 cmol(+)/-kg deeper down. The exchange complex is saturated with bases.
Management and use of Gypsisols

Gypsisols that contain only a few percent gypsum in the upper 30 cm can be used for the production of small grains, cotton, alfalfa, etc. Dry farming on deep Gypsisols makes use of fallow years and other water harvesting techniques but is rarely very rewarding because of the adverse climate conditions. Gypsisols in (young) alluvial and colluvial deposits have a relatively low gypsum content. Where such soils are in the vicinity of water resources, they can be very productive; many irrigation projects are established on such soils. However, even soils containing 25 percent powdery gypsum or more could still produce excellent yields of alfalfa hay (10 tons per hectare), wheat, apricots, dates, maize and grapes if irrigated at high rates in combination with forced drainage. Irrigated agriculture on Gypsisols is plagued by quick dissolution of soil gypsum resulting in irregular subsidence of the land surface, caving in canal walls, and corrosion of concrete structures. Dissolution of gypsum might also reduce the depth of a petrogypsic horizon to the extent that the hard pan obstructs root growth, and/or interferes with water supply to the crop and with soil drainage. Large areas with Gypsisols are in use for extensive grazing.