Chernozems
Kastanozems
Phaeozems

Peter Schad
Soil Science
Department of Ecology
Technische Universität München
Steppes

dry, open grasslands in the mid-latitudes
seasons:
- humid spring and early summer
- dry late summer
- cold winter

occurrence:
- Eurasia
- North America: prairies
- South America: pampas
Steppe soils

Chernozems: mostly in steppes
Kastanozems: steppes and other types of dry vegetation
Phaeozems: steppes and other types of medium-dry vegetation
(till 1998: Greyzems, now merged to the Phaeozems)
all steppe soils: mollic horizon
Definition of the mollic horizon (1)

The requirements for a mollic horizon must be met after the first 20 cm are mixed, as in ploughing

1. a soil structure sufficiently strong that the horizon is not both massive and hard or very hard when dry. Very coarse prisms (prisms larger than 30 cm in diameter) are included in the meaning of massive if there is no secondary structure within the prisms; \textit{and}
Definition of the mollic horizon (2)

2. both broken and crushed samples have a Munsell chroma of less than 3.5 when moist, a value darker than 3.5 when moist and 5.5 when dry (shortened); and

3. an organic carbon content of 0.6% (1% organic matter) or more throughout the thickness of the mixed horizon (shortened); and
Definition of the mollic horizon (3)

4. a base saturation (by 1 M NH$_4$OAc) of 50% or more on a weighted average throughout the depth of the horizon; and
Definition of the mollic horizon (4)

5. the following thickness:
   a. 10 cm or more if resting directly on hard rock, a petrocalcic, petroduric or petrogypsic horizon, or overlying a cryic horizon;
   b. at least 20 cm and more than one-third of the thickness of the solum where the solum is less than 75 cm thick;
   c. more than 25 cm where the solum is more than 75 cm thick
(solum: A, E, and B horizons)
Colour of the surface horizon

Chernozem: black, i.e.
moist chroma of 2 or less
if the texture is finer than sandy loam
less than 3.5
if the texture is sandy loam or coarser

Kastanozem: brown, i.e.
moist chroma of more than 2
all: to a depth of at least 20 cm,
or directly below any plough layer

Phaeozem: no additional requirements
Occurrence of secondary carbonates

Chernozem:
within 50 cm of the lower limit of the Ah
and within 200 cm from the soil surface

Kastanozem:
within 100 cm from the soil surface

Phaeozem:
free to a depth of 100 cm from the soil surface
or to a contrasting layer between 25 and 100 cm
(lithic or paralithic contact, petrocalcic horizon)
Occurrence of secondary gypsum

only possible in the Kastanozems
Additional characteristics

Chernozems:
no uncoated silt and sand grains
on structural ped surfaces

Phaeozems:
a base saturation (by 1 M NH$_4$OAc) of 50% or more to a depth of 100 cm from the soil surface, or to a contrasting layer between 25 and 100 cm
Occurrence of other diagnostic horizons

Chernozems:
no *petrocalcic* horizon between 25 and 100 cm from the soil surface

Kastanozems:
no other diagnostic horizons than an *argic, calcic, cambic, gypsic* or *vertic* horizon

Phaeozems:
no diagnostic horizons other than an *albic, argic, cambic* or *vertic* horizon, or a *petrocalcic* horizon in the substratum
Climate of the steppe soils

- more humid
- less continental
- drier
- more continental

Phaeozems

Chernozems

Kastanozems
Carbonates

dissolved in the surface horizons
transported downwards with drainage water
Phaeozems:
leached out completely
or precipitated below 100 cm
Chernozems:
precipitated within 200 cm
(and within 50 cm from the Ah)
Kastanozems:
precipitated within 100 cm
Gypsum

more soluble than carbonates
transported over a longer distance
Kastanozems:
may be precipitated within the solum
Chernozems and Phaeozems:
leached out of the solum
Climate of the Chernozems

relatively humid steppes:
6 to 8 months humid (or with snow)
(4 to 6 months arid)

over the year:
precipitation and pot. evapotranspiration +-equal

Europe and Asia:
400 to 550 mm annual precipitation
Vegetation of the Chernozems

vegetation: long grass steppe
spring and early summer:
rain and melting snow: vegetation grows well
during the summer: dry:
aboveground biomass dies back
some species: also roots die
plant residues: first:
little mineralization, little humification
late summer: too dry for microorganisms
winter: too cold for microorganisms
Animals of the Chernozems

many animals, including small mammals:
dig themselves down in the dry period
and especially in the cold winter
take along plant residues
spring: dig themselves up
leave plant residues in the subsoil
some animals (e.g. earthworms):
eat plant residues
-> excrements: organic molecules mixed with
clay minerals and oxides
Microorganisms of the Chernozems

spring: warm and humid:
microorganisms active
but:
- residues in greater depth
- residues mixed with clays and oxides
-> to a large amount transformed
into stable humus
A horizon of the Chernozems

Results: A horizon
- with high humus content
- thick
additionally: black:
- many Ca-humates (salts of humic acids)
- result of fires
Regional distribution of Chernozems

Chernozems cover an estimated 230 million hectares worldwide, mainly in the middle latitude steppes of Eurasia and North America, north of a zone with Kastanozems. Figure 1 presents an overview of their main areas of occurrence.
Chernozem in western Siberia
Chernozem in western Siberia
with clearly visible secondary carbonates
Climate of the Kastanozems

drier than Chernozems:
2 to 5 months humid (or with snow),
7 to 10 months arid
over the year:
pot. evapotranspiration higher than precipitation
Europe and Asia:
200 to 500 mm annual precipitation
Regional distribution of Kastanozems

The total extent of Kastanozems is estimated at about 465 million hectares. Major areas are in the Eurasian short grass steppe belt (southern Ukraine, southern Russia, and Mongolia), in the Great Plains of the USA, and in Mexico, southwestern Brasil, and the pampa regions of Northern Argentina, Uruguay and Paraguay. Figure 1 shows the worldwide occurrence of Kastanozems.
Distribution of the Kastanozems

steppe areas of the northern hemisphere:
- from the Chernozems towards the equator (towards the subtropical deserts)
- from the Chernozems towards the centre of the continents (towards the mid-latitude deserts)

steppe areas of the southern hemisphere:
western Patagonia

tropics and subtropics:
- high mountain areas: timberline
- lowlands: deciduous dry forests (e.g. Chaco)
A horizon of the Kastanozems

short grass steppe
drier than Chernozems
-> less biomass production
-> less humus
-> less Ca-humates
-> brown, like chestnuts
-> less bioturbation
-> A horizon less thick
Kastanozem in western Siberia
Climate of the Phaeozems

more humid than Chernozems:
at least 8 months humid (or with snow);
4 arid months maximum

over the year:
precipitation higher than pot. evapotranspiration

Europe and Asia:
500 to 700 mm annual precipitation
Regional distribution of Phaeozems

Phaeozems cover an estimated 190 million hectares worldwide. Some 70 million hectares of Phaeozems are found in the (sub-)humid Central Lowlands and easternmost parts of the Great Plains of the USA. Another 50 million hectares of Phaeozems are in the subtropical pampas of Argentina and Uruguay and the third largest distribution area of Phaeozems (18 million hectares) is in northeastern China. Smaller, mostly discontinuous areas, are found in Central Europe, notably the Danube area of Hungary and adjacent parts of Yugoslavia and in montane areas in the tropics. Figure 1 presents the main Phaeozem areas.
Distribution of the Phaeozems

steppe areas of the northern hemisphere:
- from the Chernozems towards the poles
  -> cooler summer
- from the Chernozems towards the sea
  -> seasons less pronounced
    (summer cooler and wetter, winter warmer)
subtropics: pampa in northern Argentine,
  Uruguay and southern Brazil
 tropics:
  - high mountain areas: timberline
  - lowlands: transition from forest to savanna
A horizon of the Phaeozems

transition from steppe to forest
cooler summer -> less biomass production
-> less humus
wetter summer and warmer winter
-> some mineralization in late summer and in winter -> less humus
warmer winter -> less bioturbation
results:
- A with lower humus content
- A less thick
- A not always black
Phaeozem in western Siberia
Phaeozem under deciduous forest in the eastern Bolivian lowlands
Phaeozem in the grasslands above the timberline in the Bolivian High Andes (ca. 4400 m asl)
Fertility of steppe soils

very fertile, especially Chernozems
humus-rich, deep A horizons
chemically:
  high nutrient supply
  problems with P (Ca-phosphates)
  problems with Fe and Mn (high pH)
physically:
  high plant available water capacity
  good aeration
  easy for root penetration and ploughing
Land use on steppe soils

mostly used as arable land for crop production
also pasture land (especially Kastanozems)
sometimes forest (especially Phaeozems)
effects of agricultural use:
- less input of plant residues
- more mineralization (e.g. due to tillage)
-> less humus in the soil
-> more CO$_2$ in the atmosphere